Professor Lars Vegard's Contribution to Auroral Research

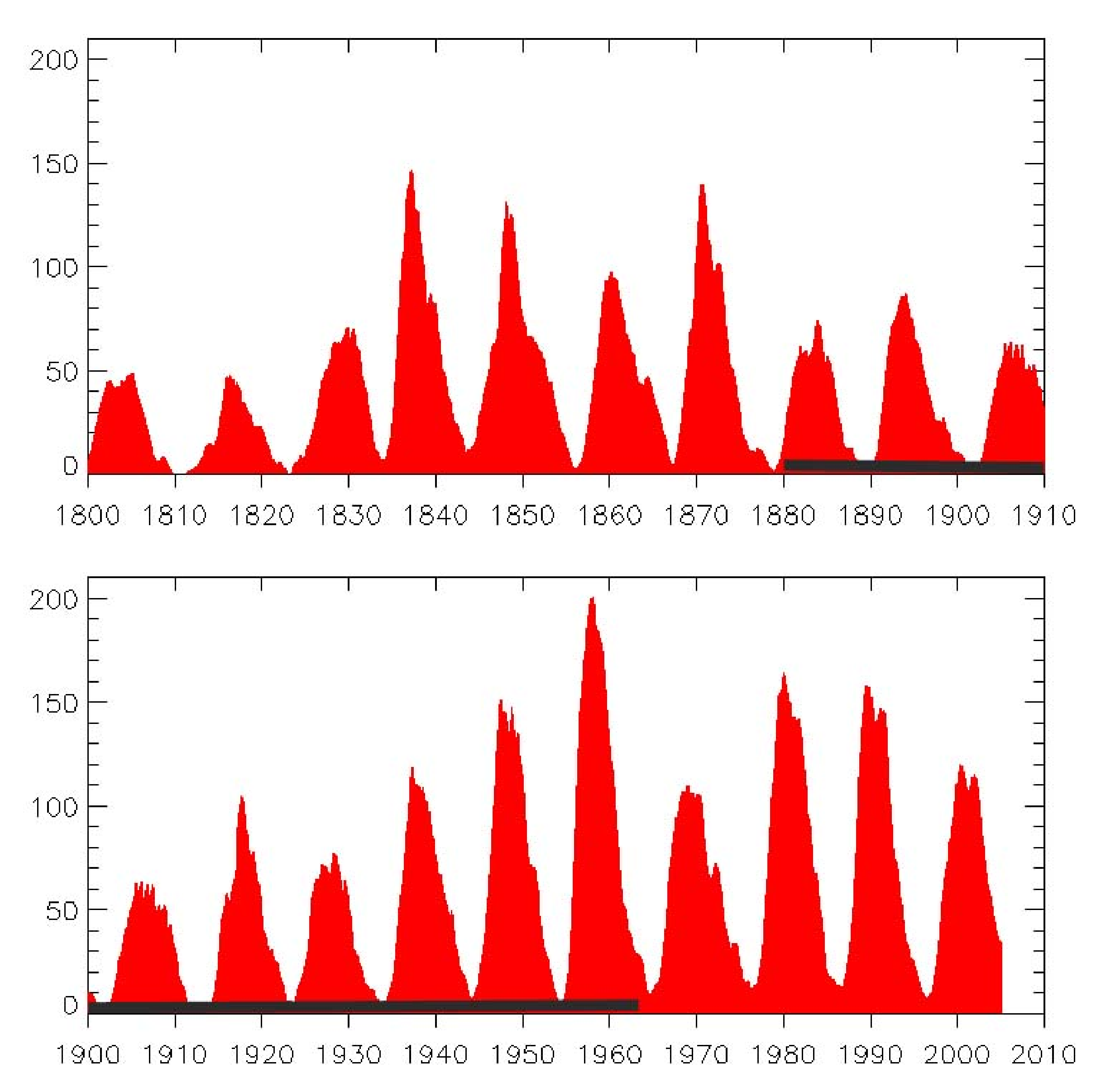
A sixty year odyssey of curiosity, patience, and determination

by

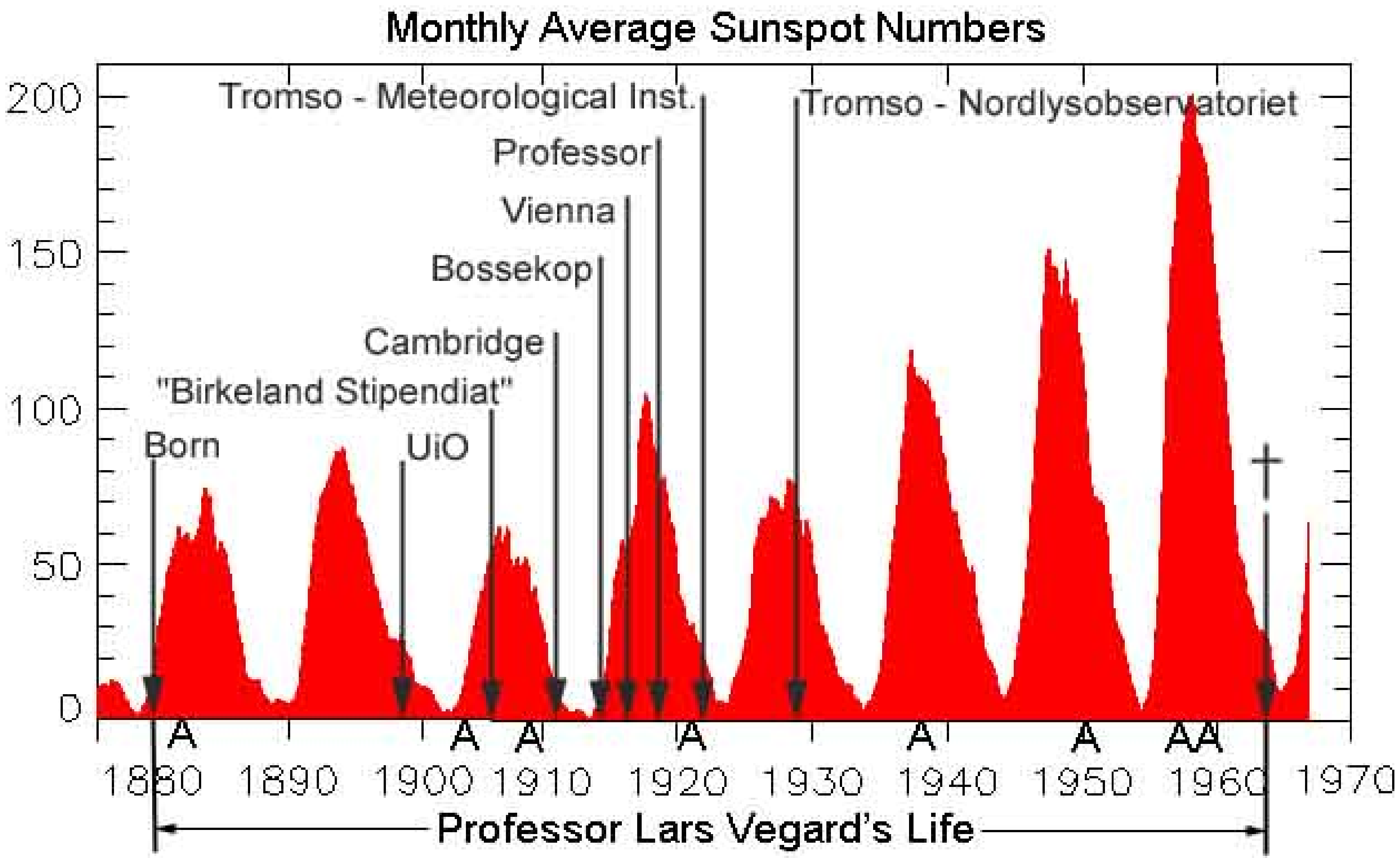
Prof. Emer. Charles Deehr
University of Alaska Fairbanks

The Span of Years

- Lars Vegard
- Born 1880
- Died 1963
- 8 Sunspot Cycles
- Nos. 12 – 16 at turn-of-century low.
- Nos. 17, 18 & 19 grew to largest observed.

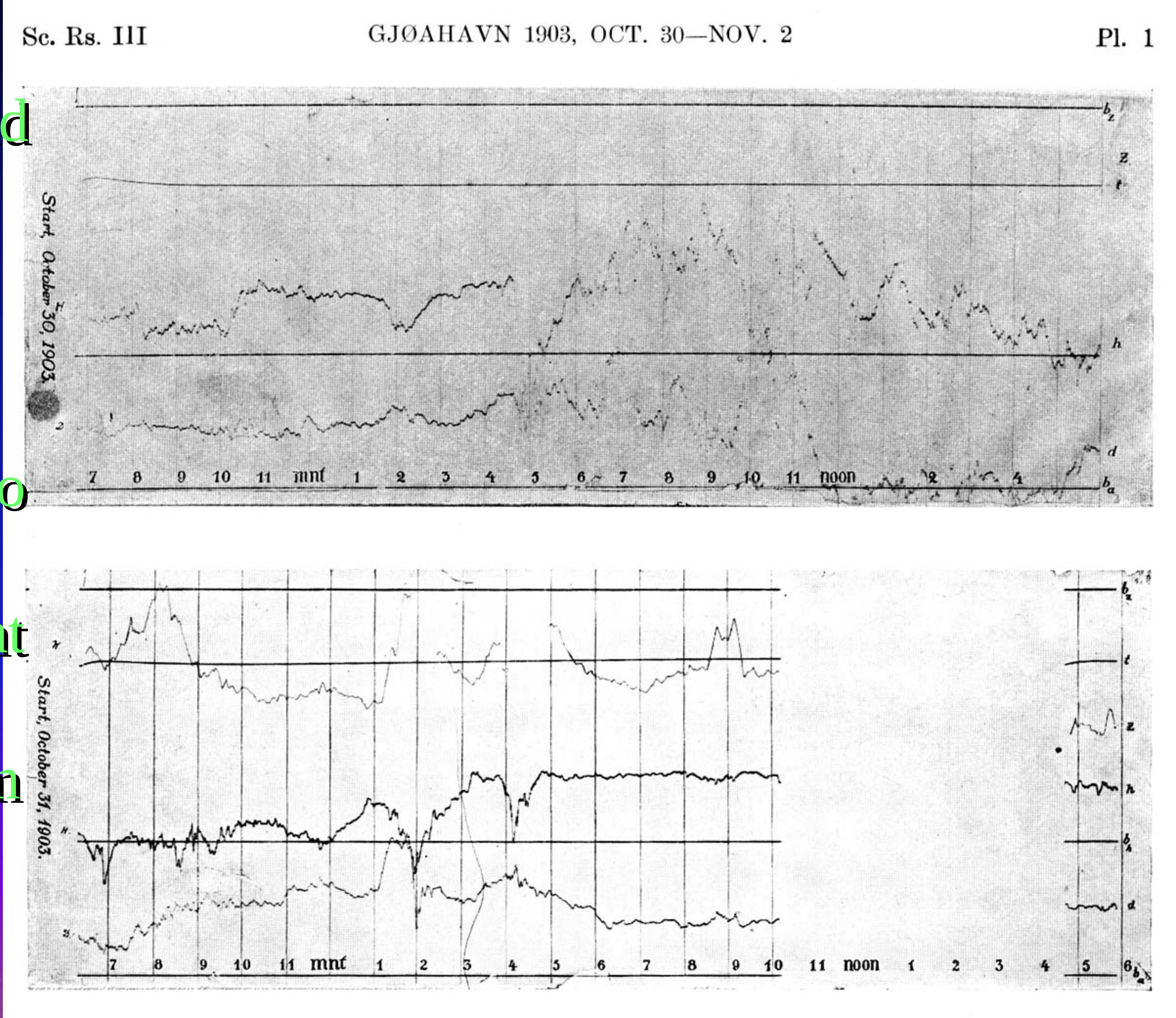


Preparations



Gjøahavn, 31 Oct. 1903

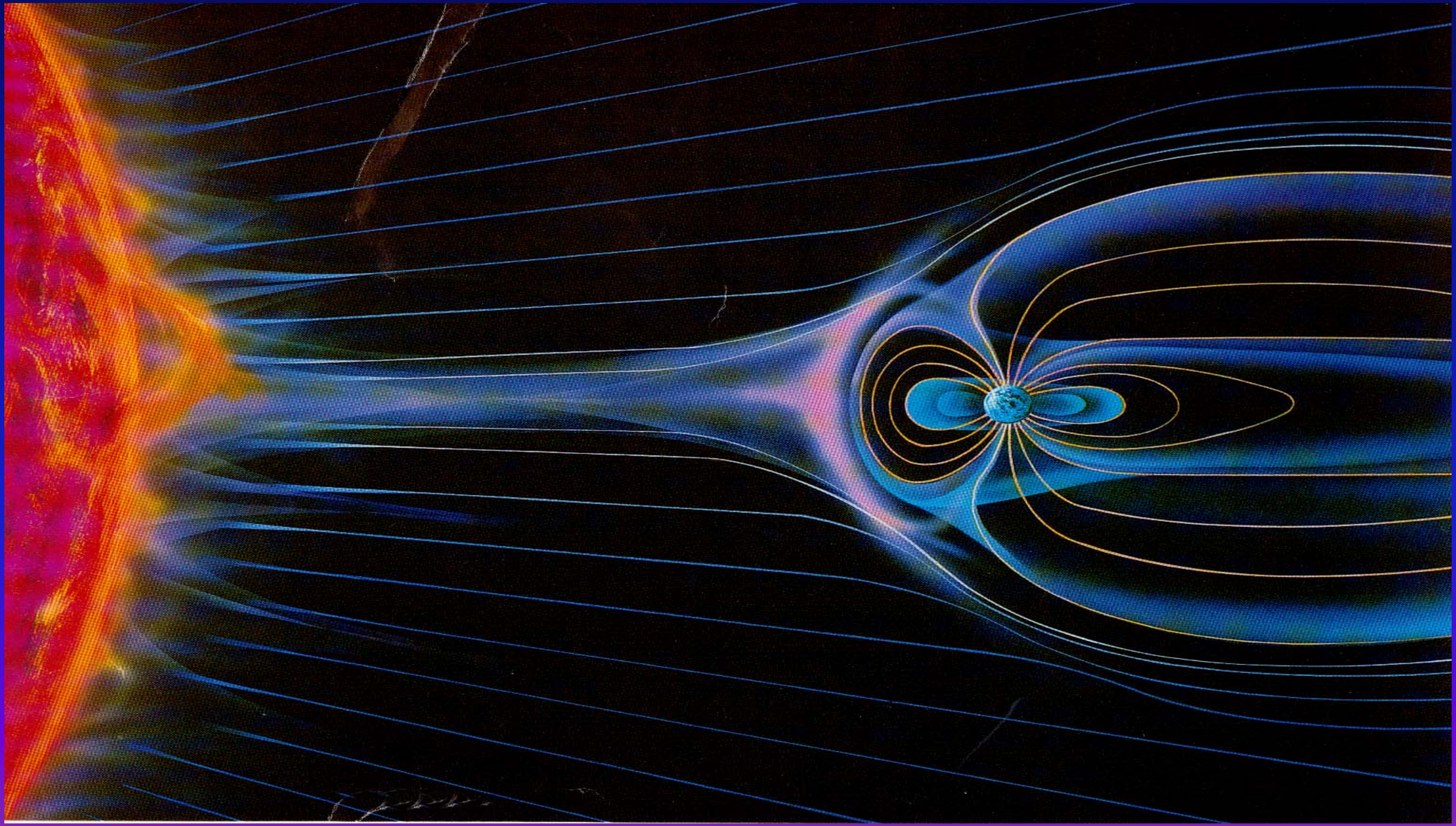
- As Vegard Birkeland and Størmer watched the great aurora of 31 Oct., Amundsen no doubt stared in amazement at the first magnetogram at Gjøahavn



Professo

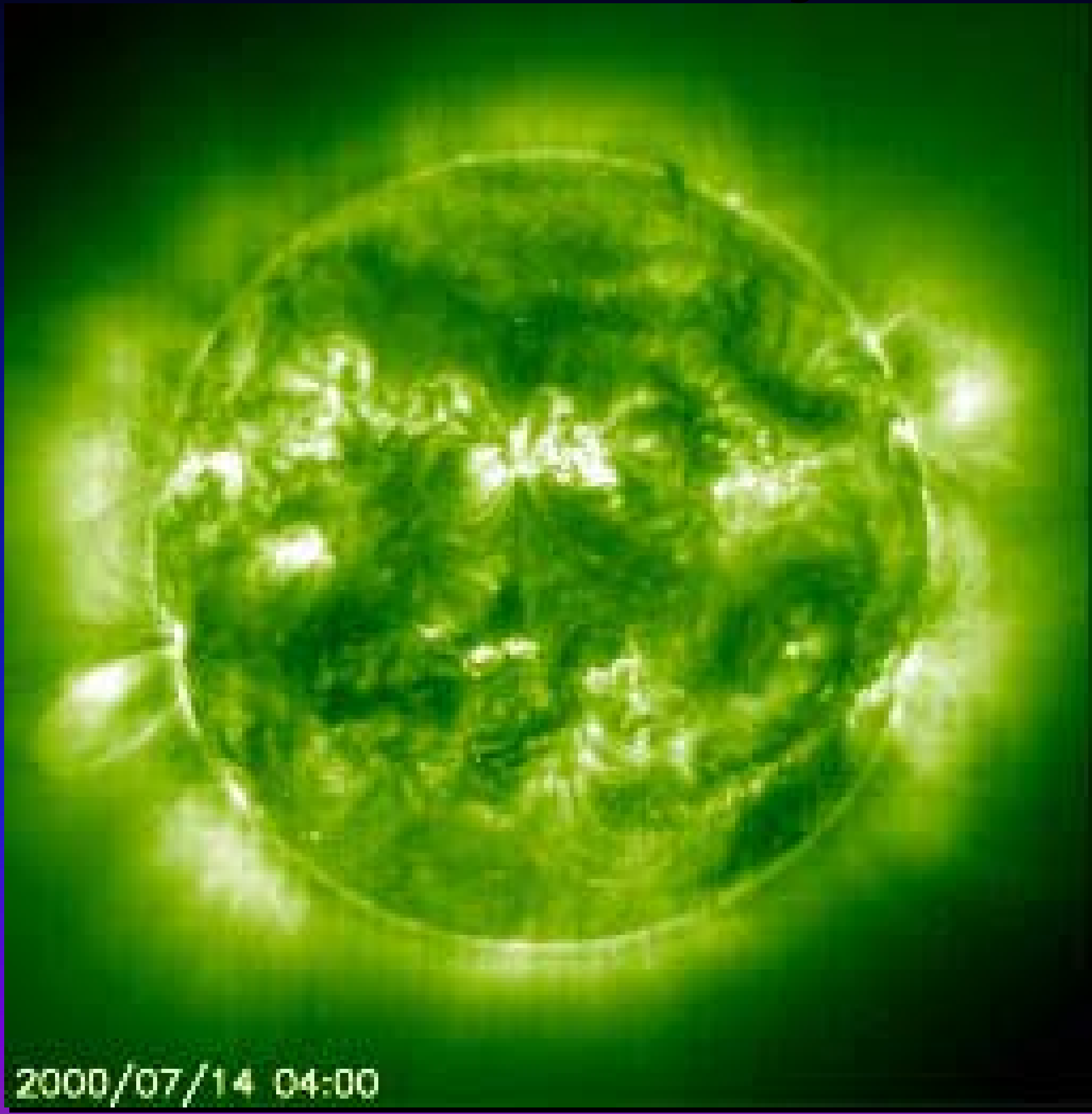
E-mail from the Solar System

- The particles from the sun activate the magnetosphere to accelerate magnetospheric particles to make aurora.



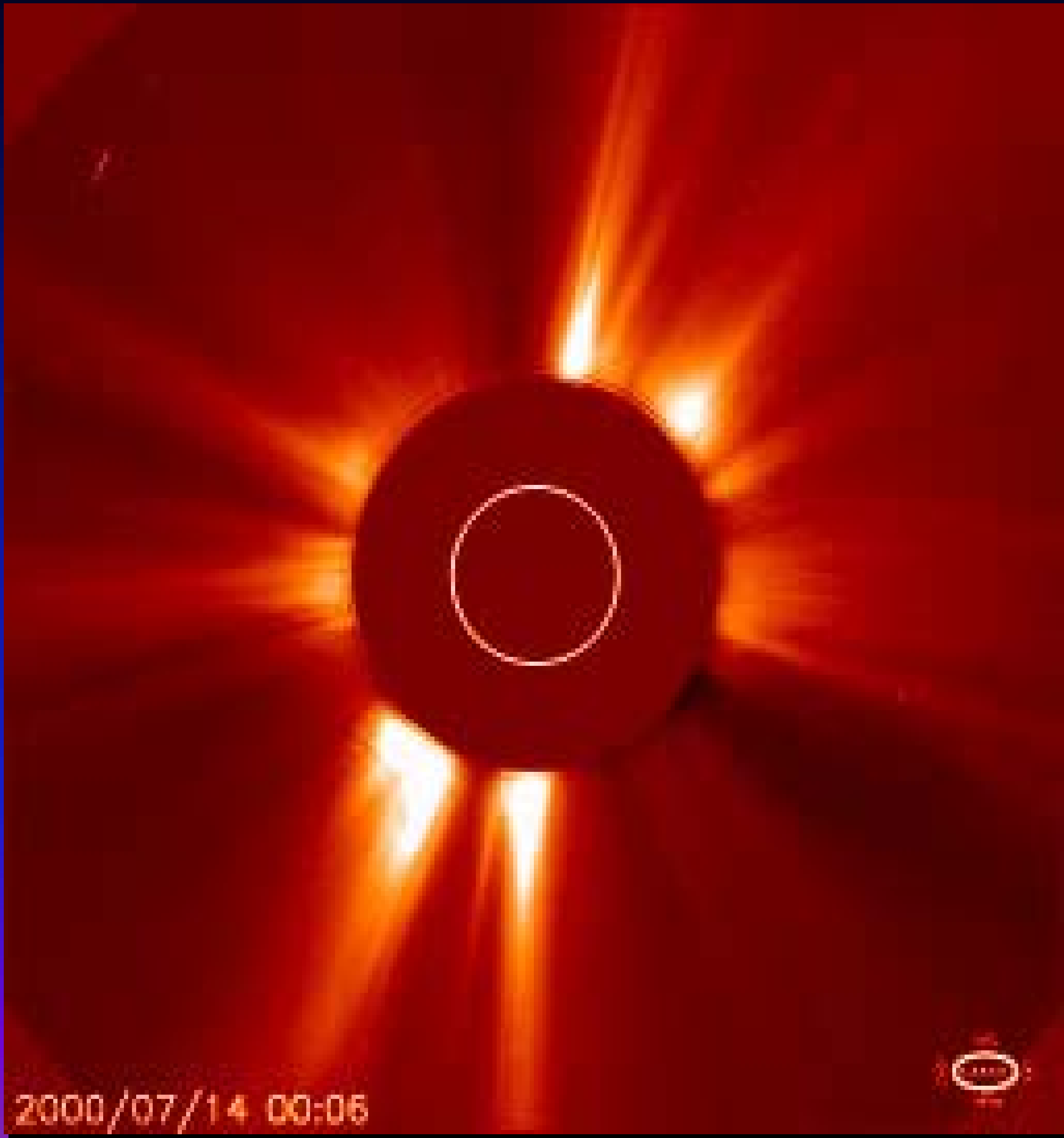
The Large Solar Event of July 14

- A series of events began on July 10, 2000, culminating in the large flare of July 14.
- The X-ray flux was large enough to disturb the imagers on the SOHO satellite



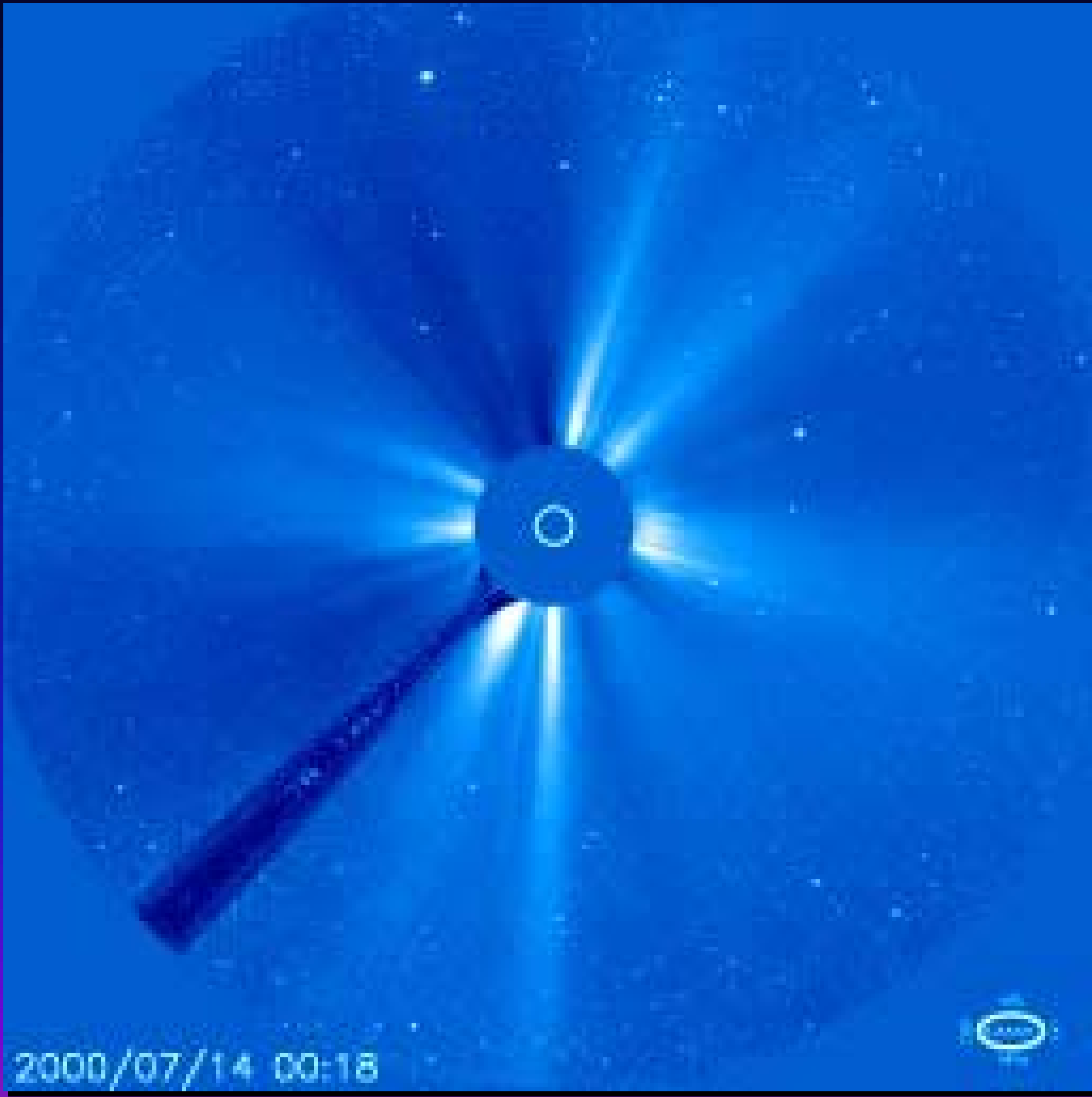
The Solar Corona

A halo coronal mass ejection (CME) was associated with the flare and the ejecta near the sun were spectacular.



Wide-field Solar Corona

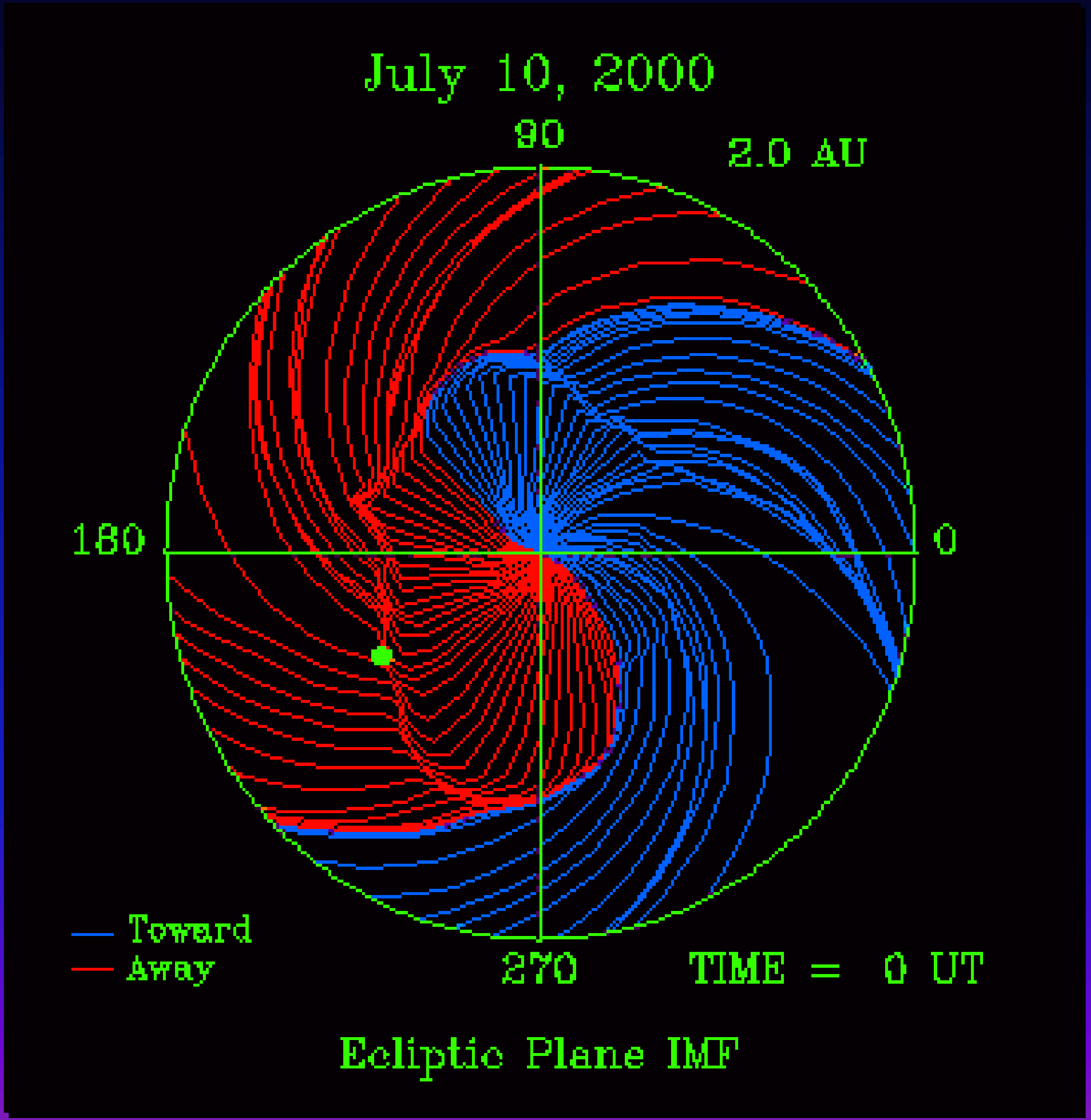
- The wide angle coronagraph followed the ejecta even farther from the sun.
- This material propagated an invisible shock wave toward Earth.



Model of the Solar Wind

A model of the solar wind shows the interplanetary shocks associated with the events of July 10 - 19, 2000.

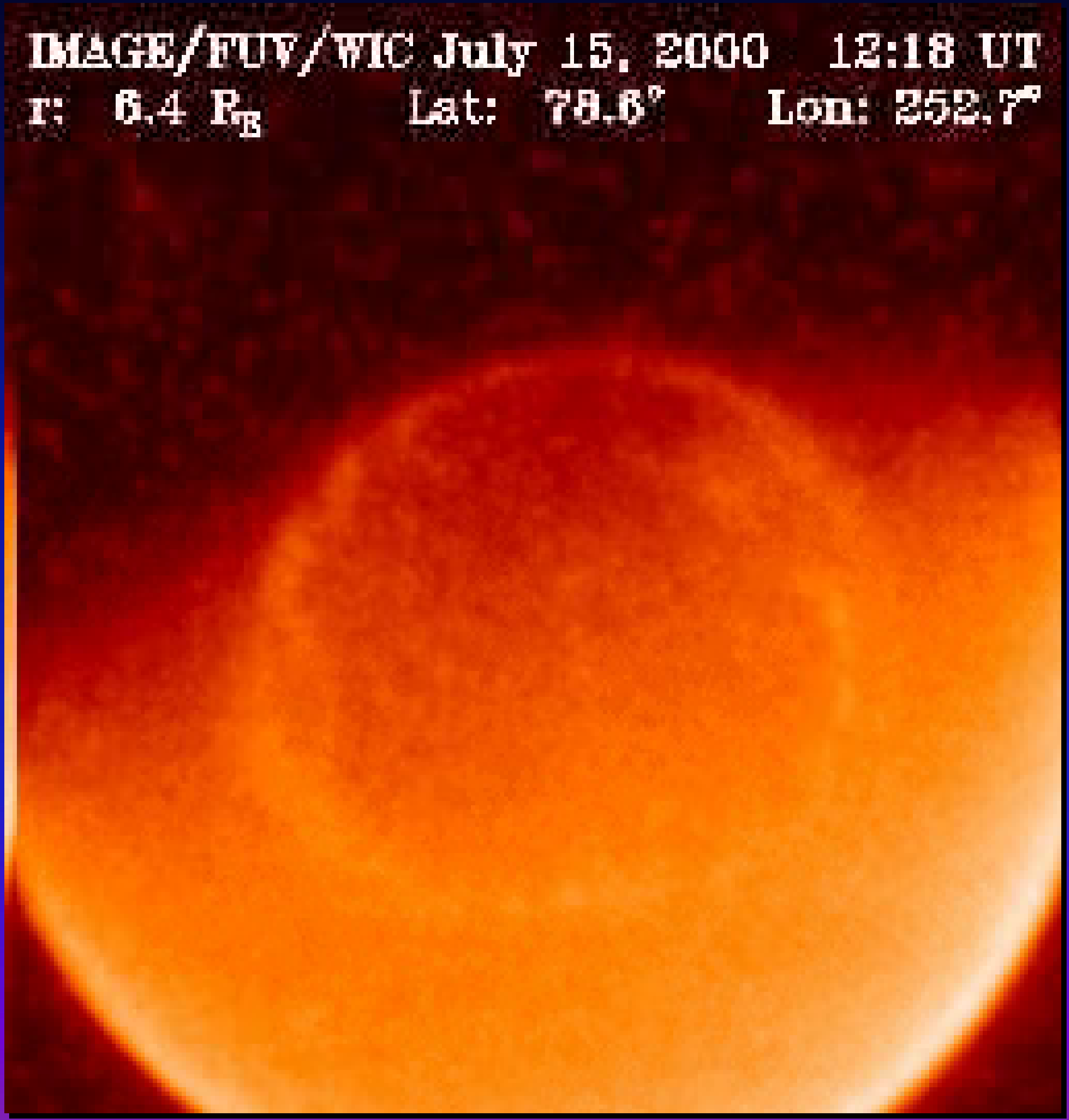
The Sun is at the center and the Earth is the green dot.



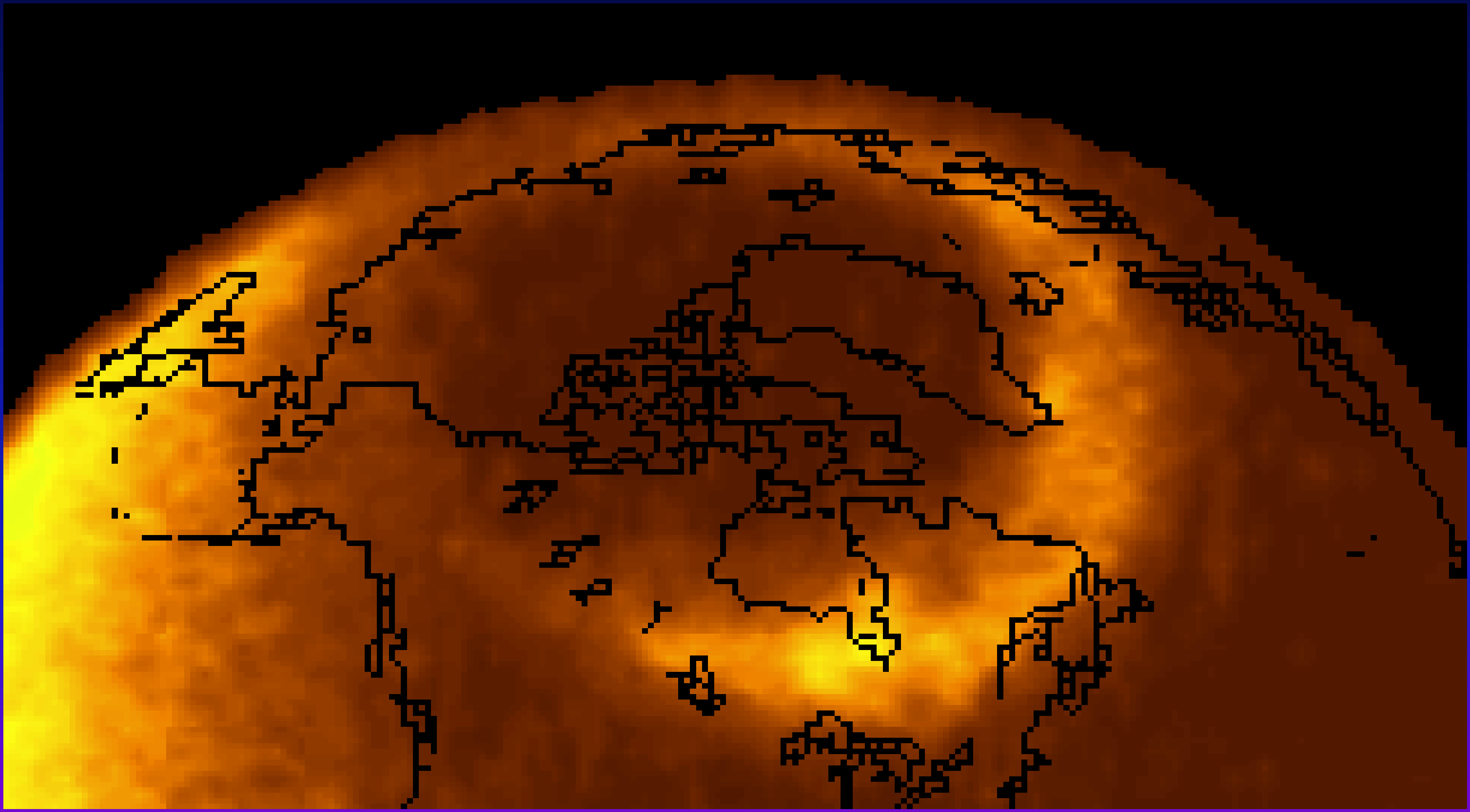
Auroral Sequence on July 15th

The aurora in the northern hemisphere is visible here in the ultraviolet observation from the IMAGE satellite.

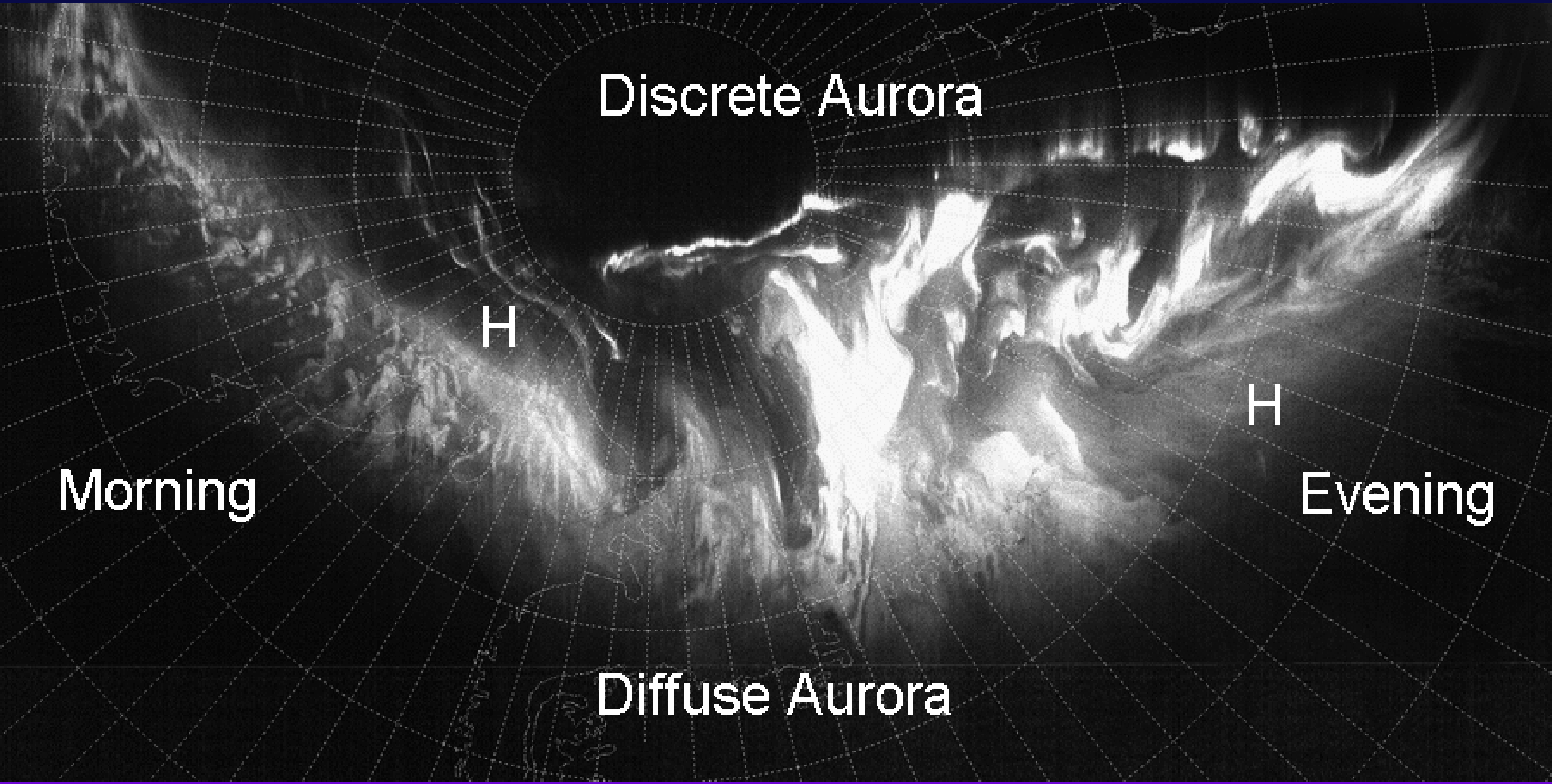
Watch for the pressure pulse aurora after 1600 UT.



The Biggest Show on Earth

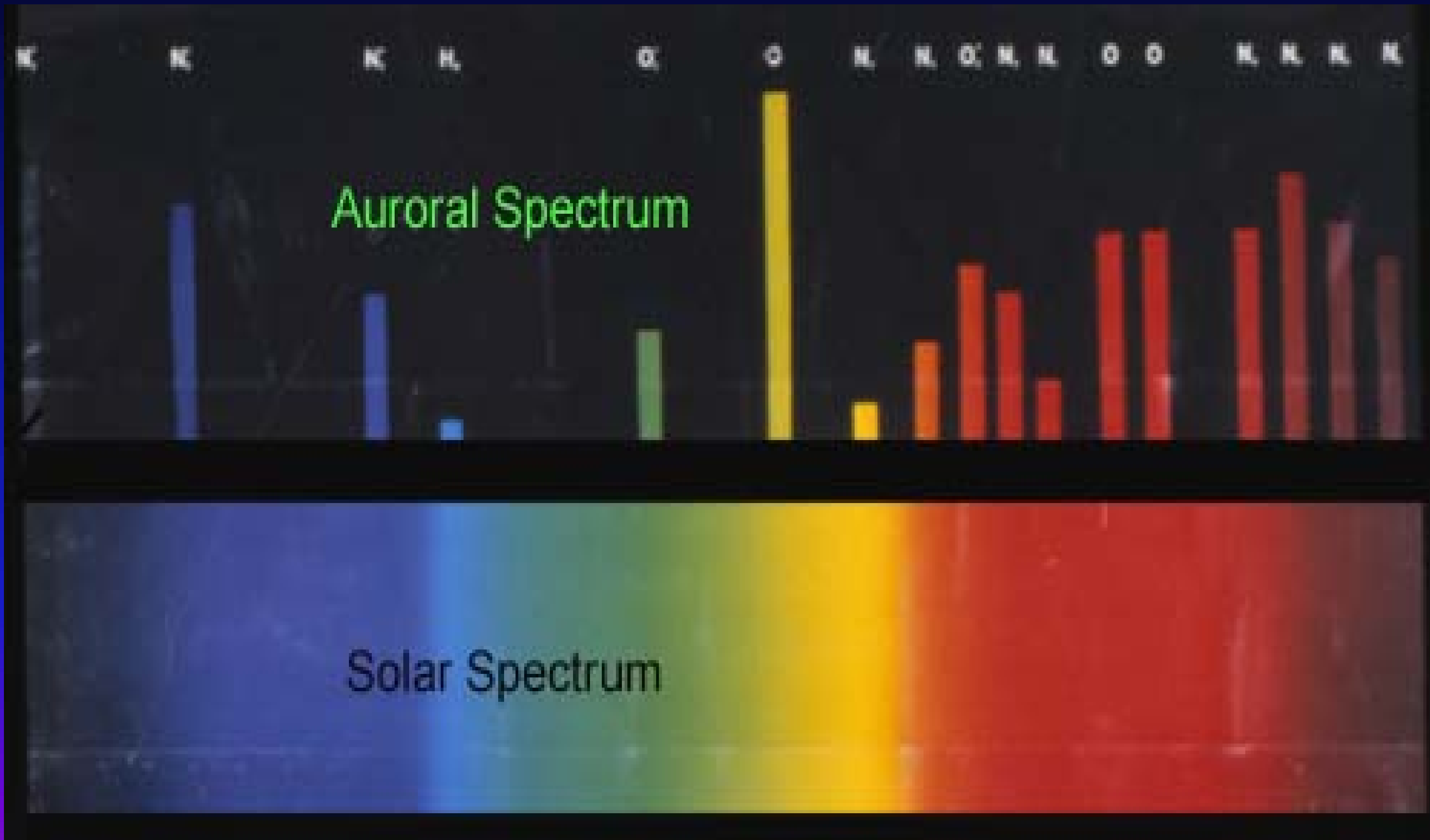


Geographic Pattern of the Aurora



View from the Shuttle

Color from the Earth's Atmosphere



Classify According to Color

- Type A - crimson upper border
- Type B – magenta lower border
- Type c – green arc
- Type d – red overall
- Type e – magenta and green lower border
- Type f – blue or purple

Classify According to Color

Type B

Magenta

Lower

Border

Classify According to Color

Type c

Normal

Green,

Gray

Classify According to Color

Type d
Great
Red
Aurora

Classify According to Color

Type e

Magenta

Moving

Ahead

Of

Green

Classify According to Color

Type f

Blue or

Purple

Sunlit

Aurora

Classify According to Color

Vegard defined the first two classifications.

Type A is associated with Solar maximum and low latitude aurora.

Type B is associated with Solar minimum and high latitude aurora.

Classify According to Color

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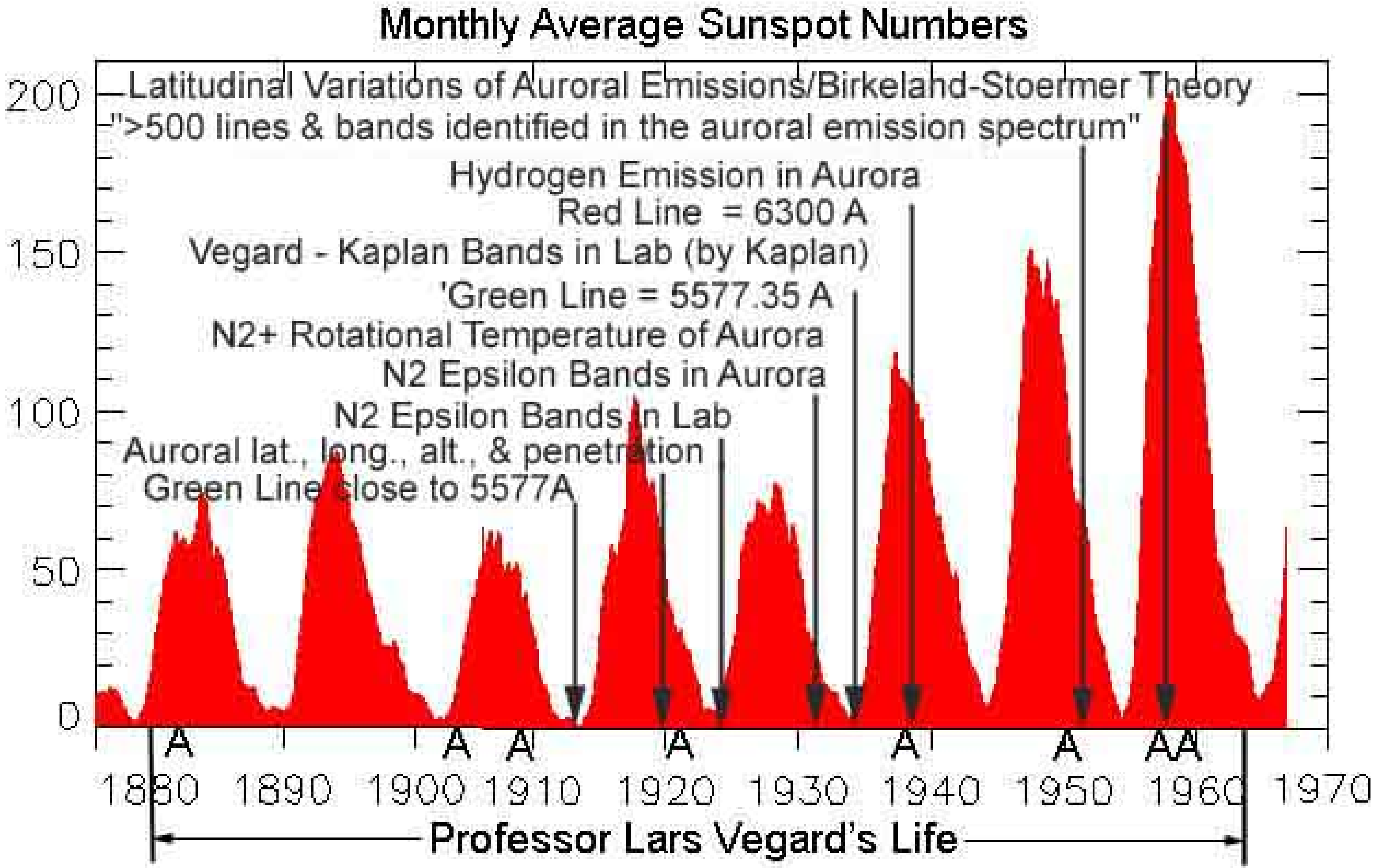
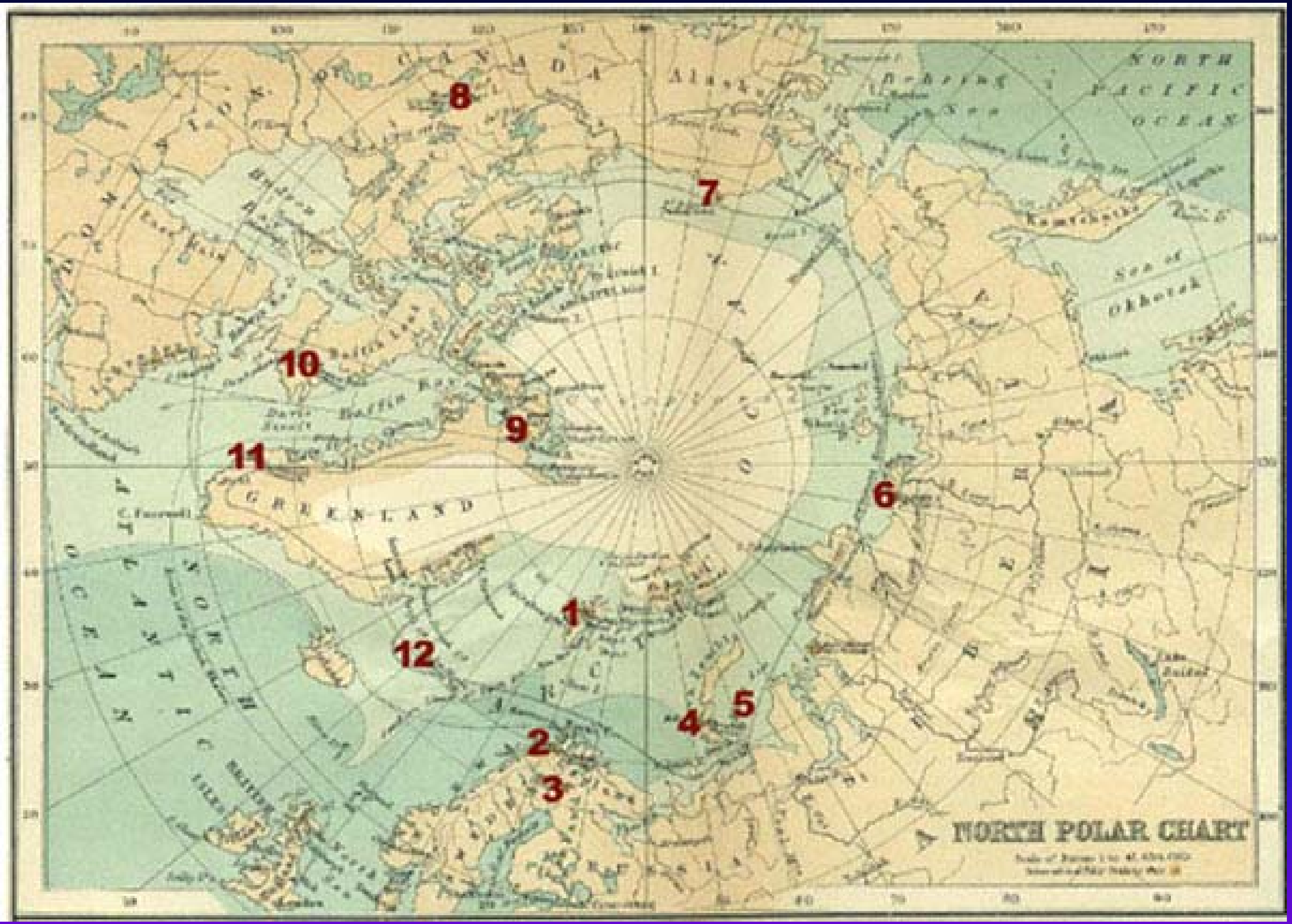
Vegard’s Auroral Research



Bossekop Field Trip, Winter 1912-13

- Vegard and Krogness spent the winter of 1912-13 at Bossekop and Haldde to measure the aurora using parallactic photography.



Bossekop, The Field Trip

- The Bossekop – Haldde baseline for parallactic photography is 12.4 km

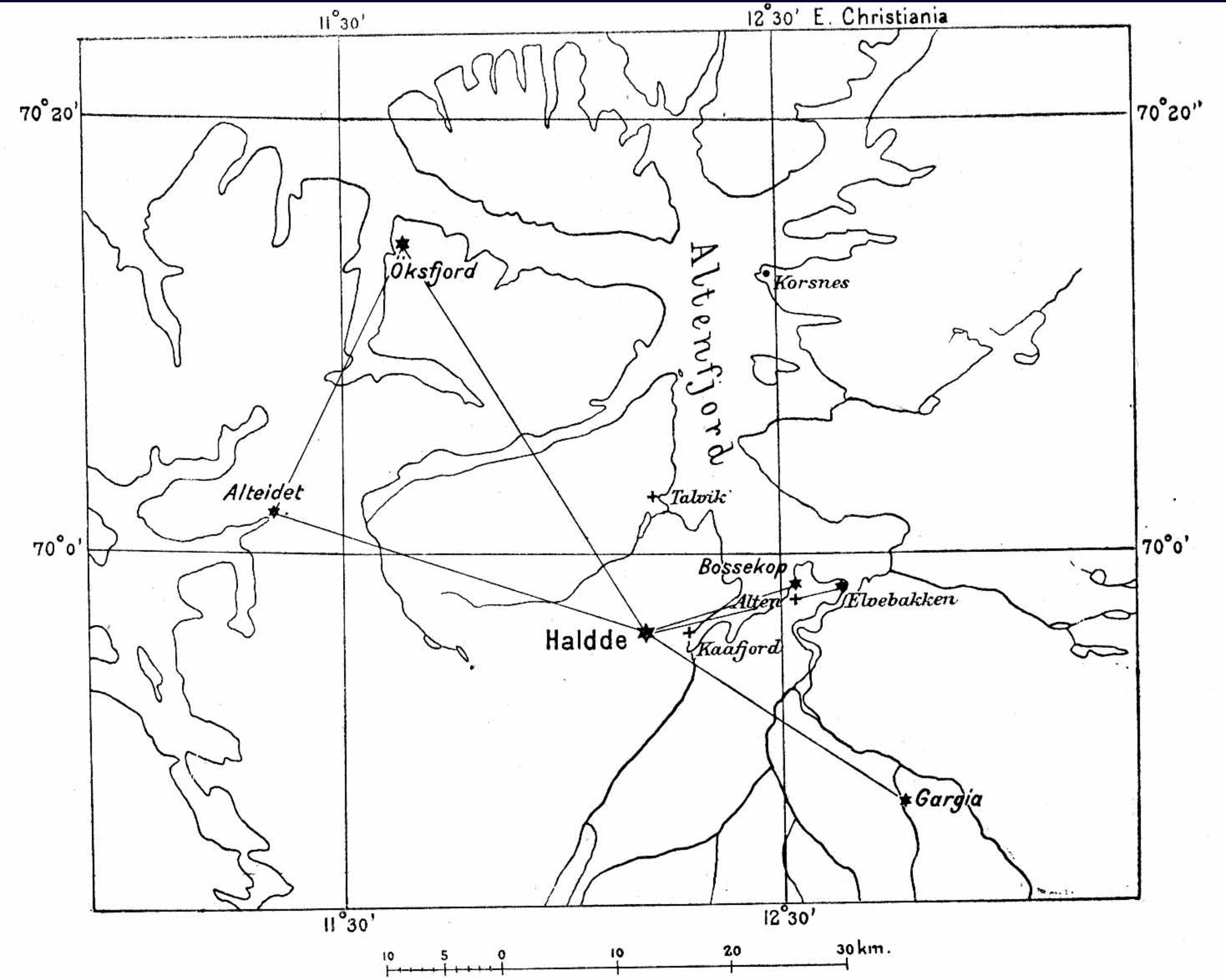
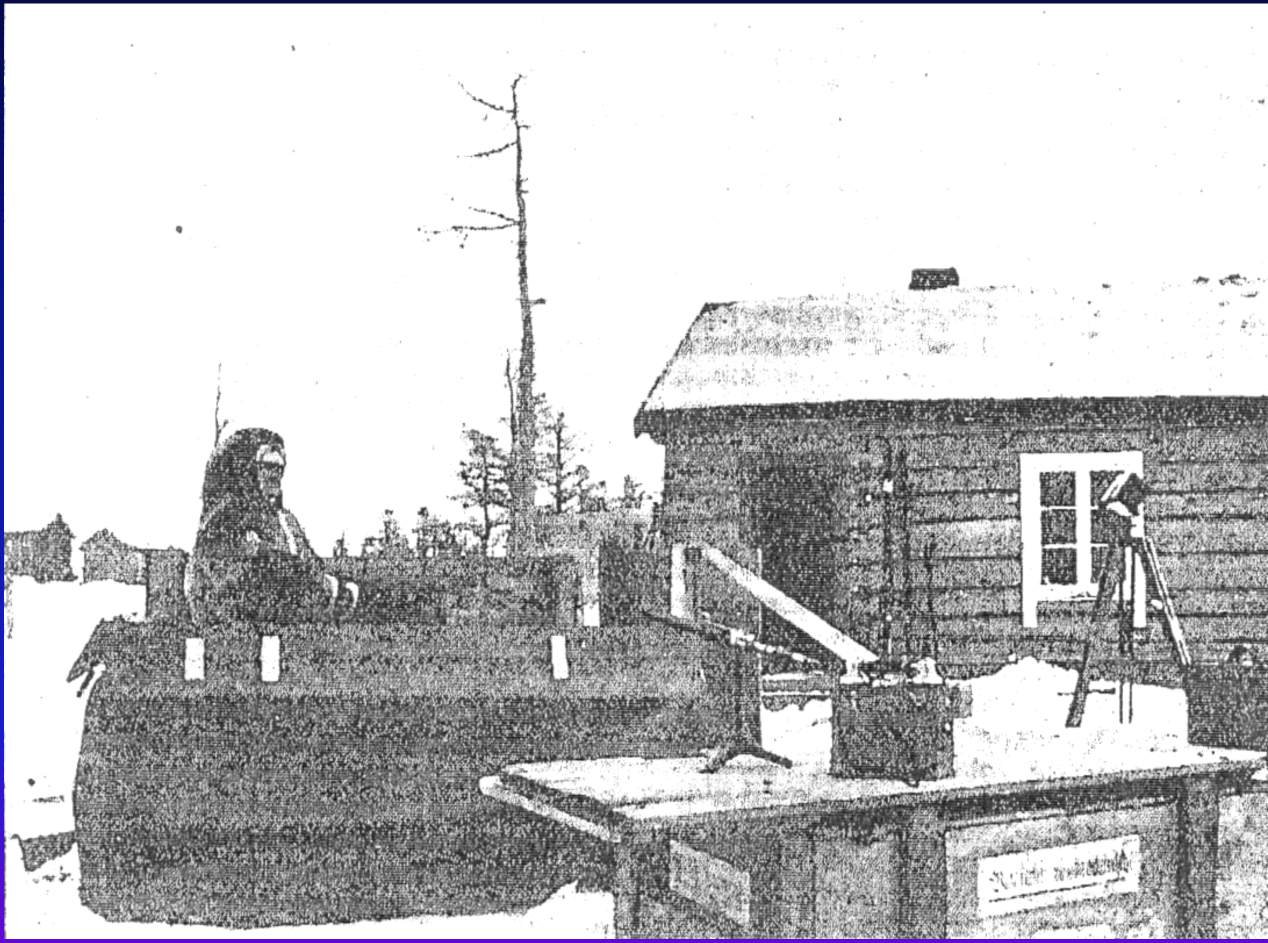


Fig. 2.

Bossekop, The Field Trip

- Vegard's station was at the Bossekop field station.
- It had been part of the International Polar Year network.



Bossekop, The Field Trip

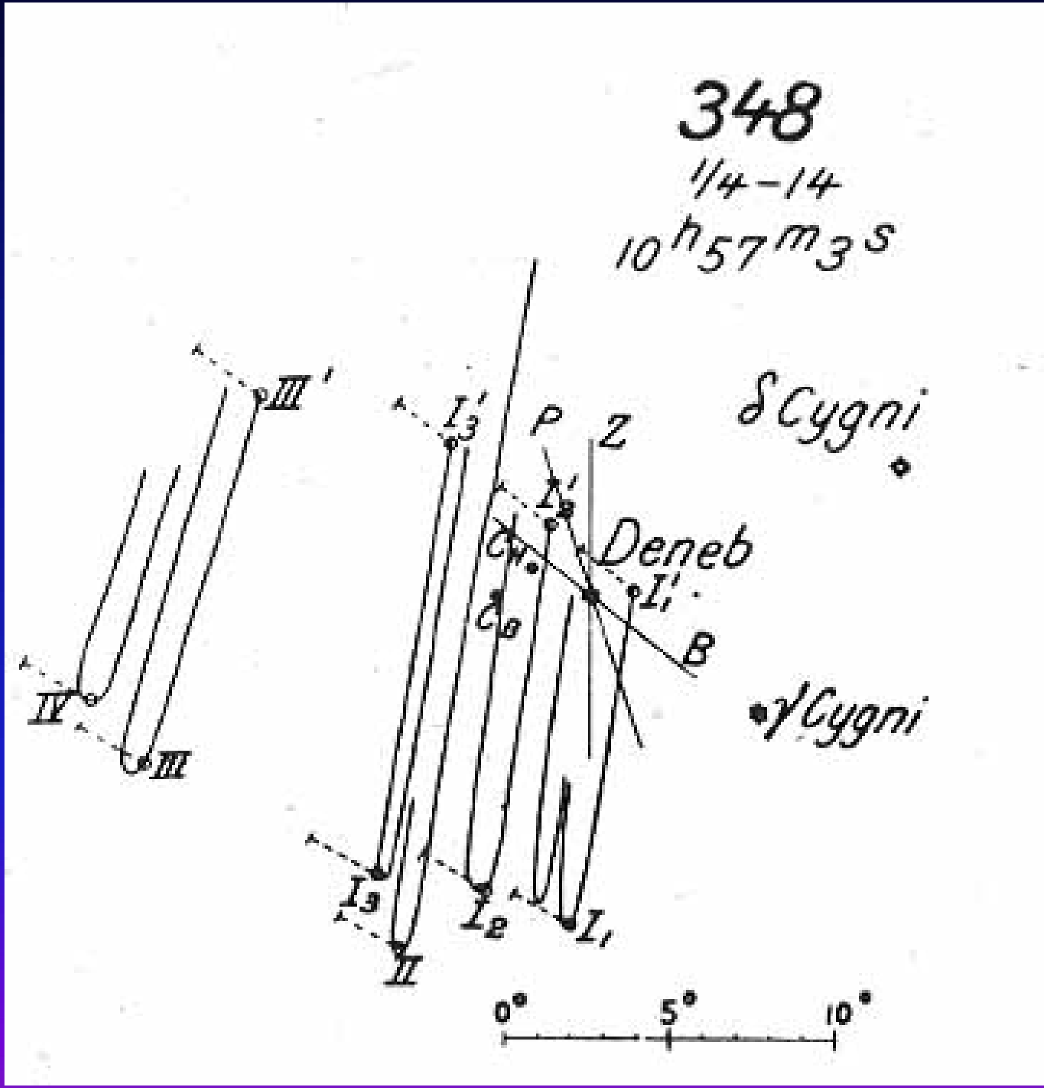
- Krogness held forth at the Haldde field station.
- It was more exposed and not as good for spectrographic work as Bossekop.

Parallactic Photography

- Two cameras located 5 to 50 km apart
- Communications between photographers
- Photographers agree on exposure time and direction
- Line up star fields
- Measure distance between points on auroral form.

Parallactic Photography

- Showing photograph pair number 348 with stars superimposed and distances between forms marked at parts of the images that are recognizable from both stations.



Arc Altitude

- Distance to the aurora is measured from two photographs.
- Altitude above ground is found by trigonometry from angles and distance.

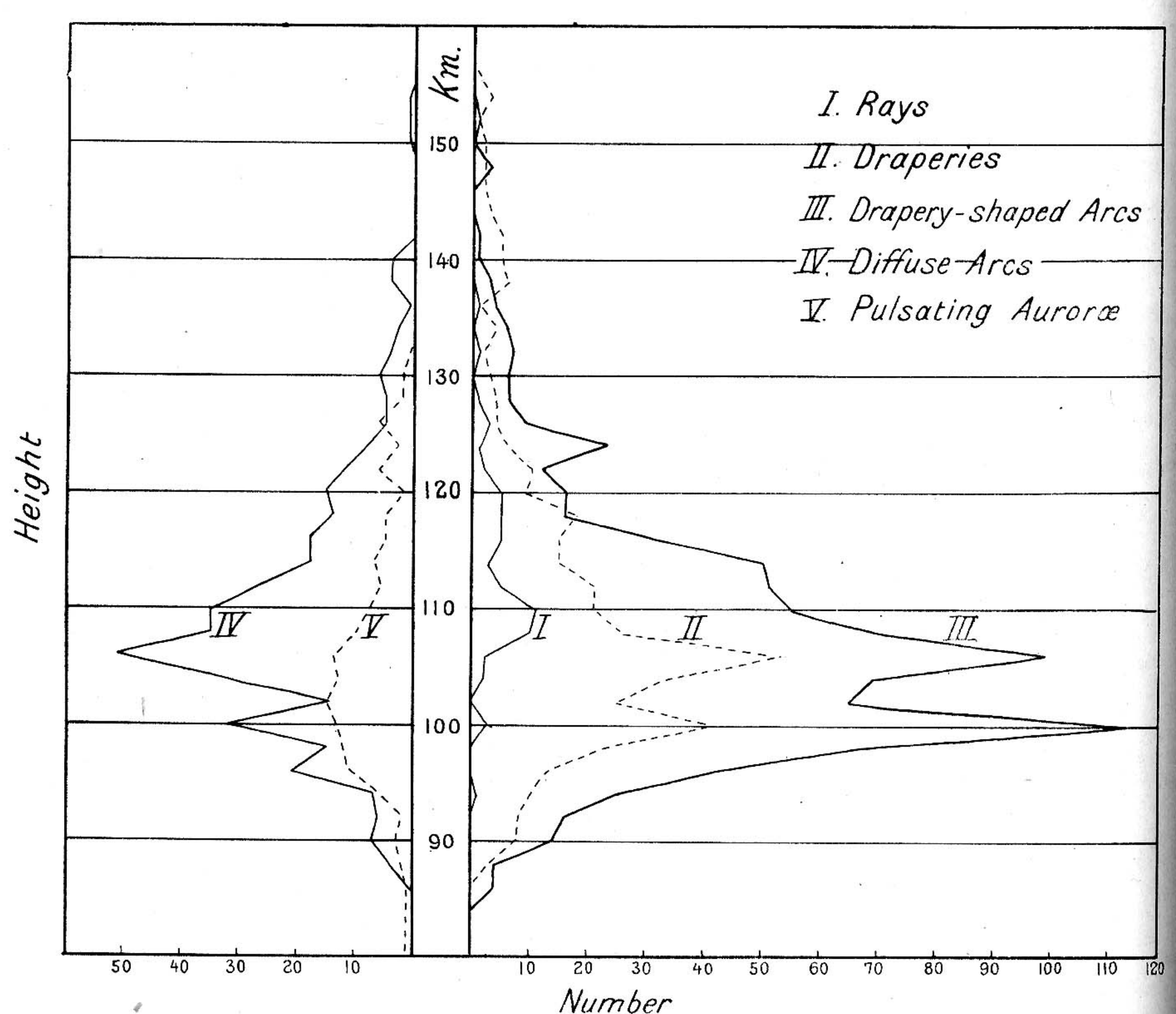
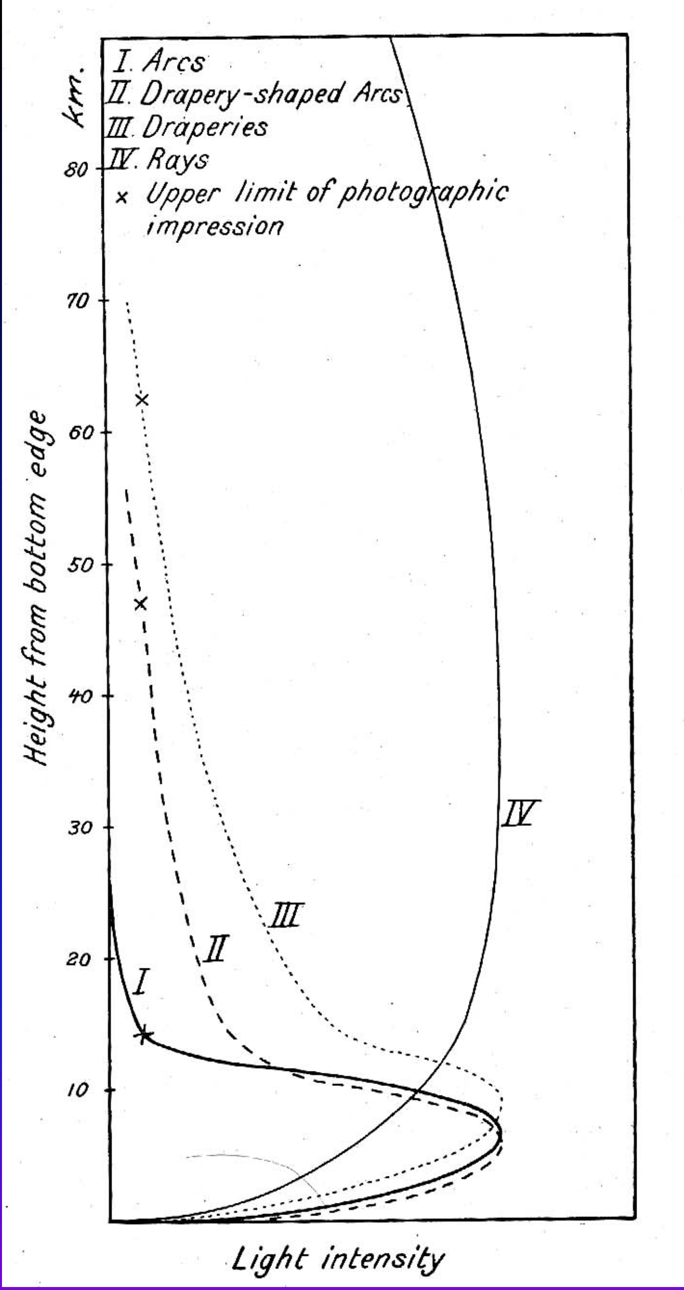


Fig. 19.

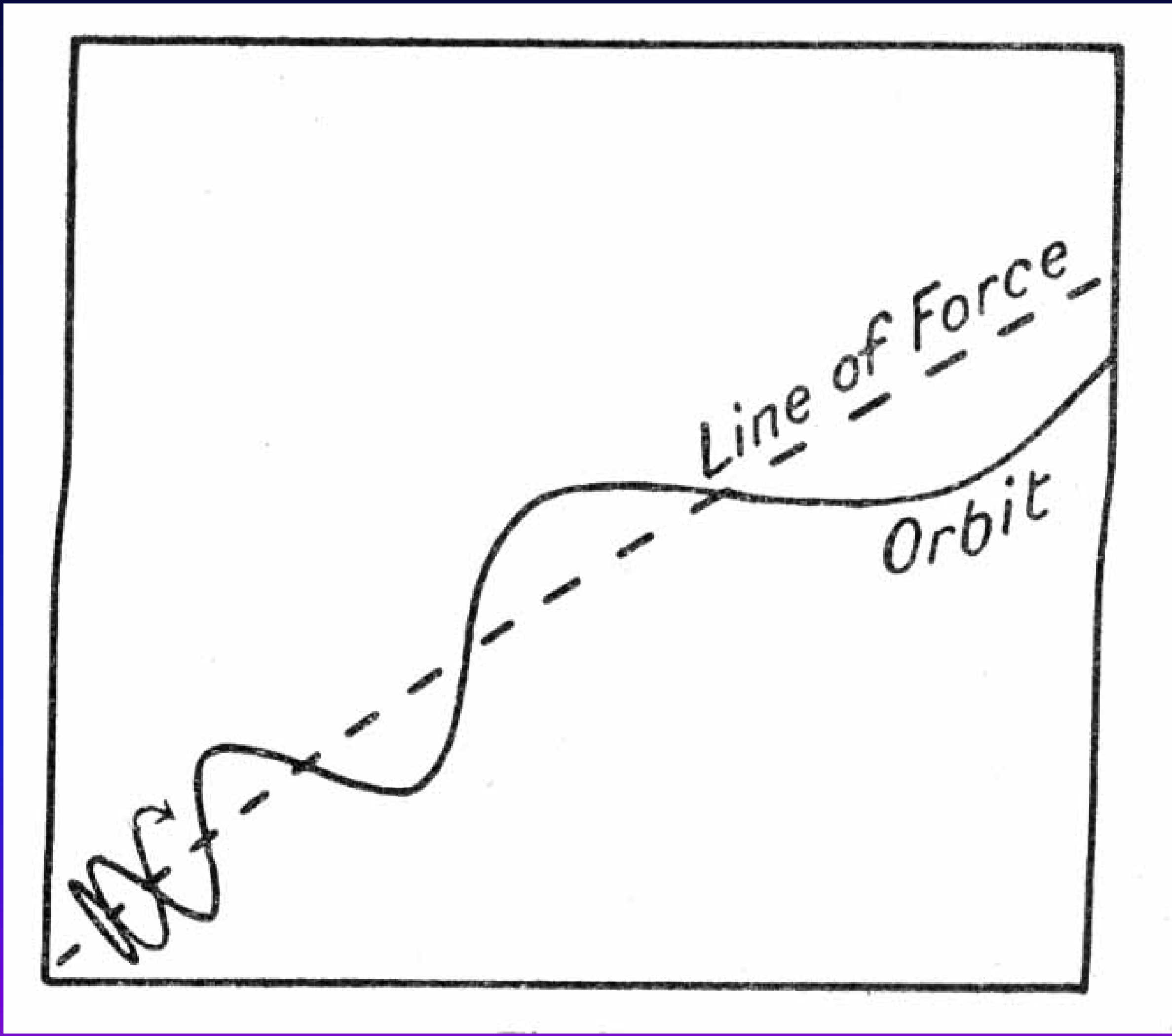
Arc Length

- Distance on pictures between two points is proportional to distance from observer to aurora.
- Vegard wanted to know if he could reproduce the various arc lengths with different energetic particles.



Charged Particle in Magnetic Field

- Vegard understood the motion of charged particles in magnetic fields.
- He calculated how far the particles would penetrate the atmosphere and compared it to his measurements of arc lengths.



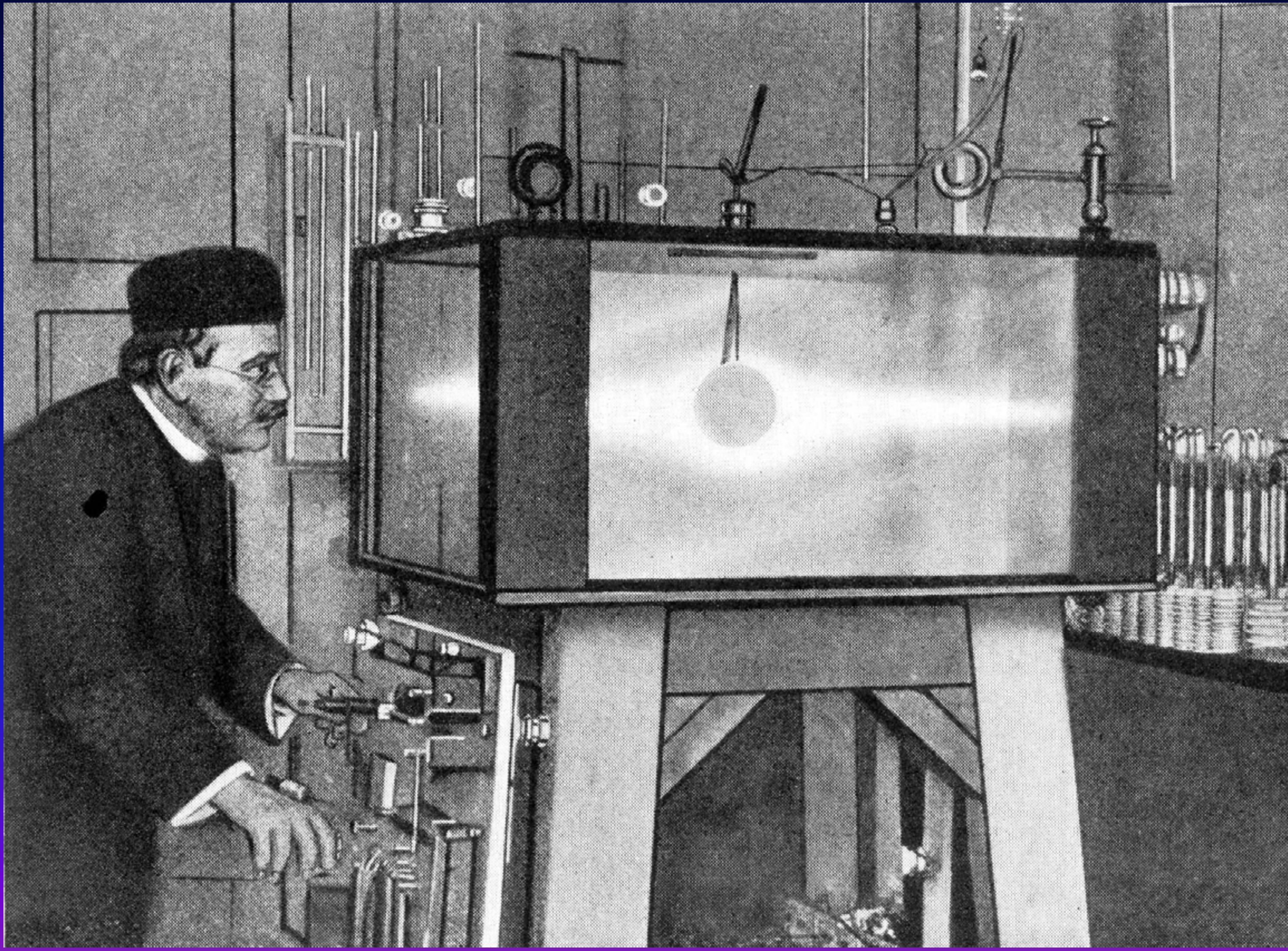
Energetic Particles

Vegard compared the observed arc lengths with what would be expected from different particles of different energy. Unfortunately he had relatively few sources of energetic particles available to him so it was impossible to differentiate any one of them as the cause of the aurora.

• Alpha particles	Ionized He atoms
• Beta particles	Electrons
• Gamma rays	EM waves
• Kathode strahlen	Electrons
• Kanal strahlen	Ions

Auroral Arc Alignments

- The Birkeland – Størmer theory, however, suggested that the auroral precipitation zone would have a spiral shape.



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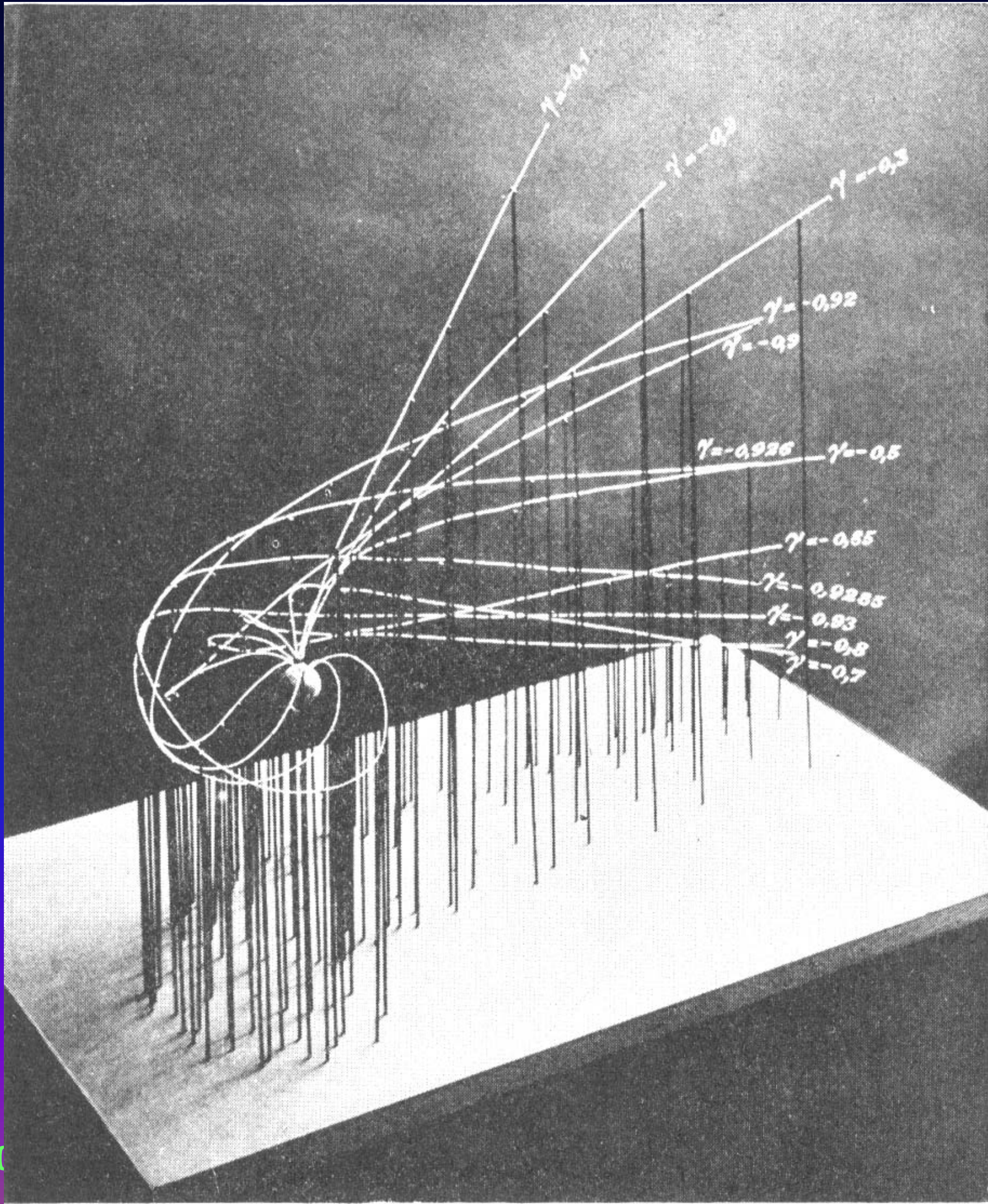

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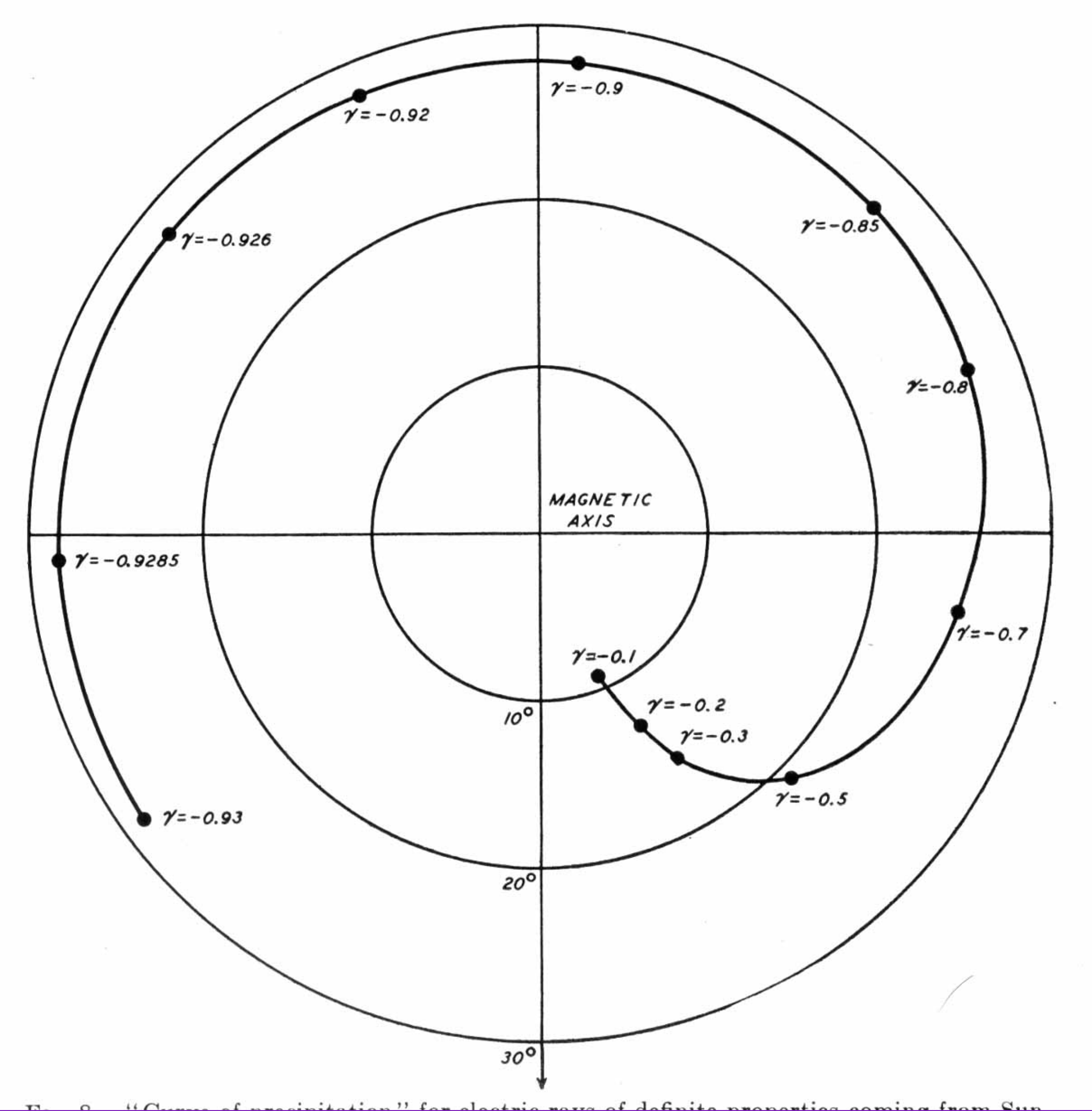


Auroral Arc Alignments

- The Birkeland – Størmer theory, however, suggested that the auroral precipitation zone would have a spiral shape.
- So Vegard measured arc alignments.

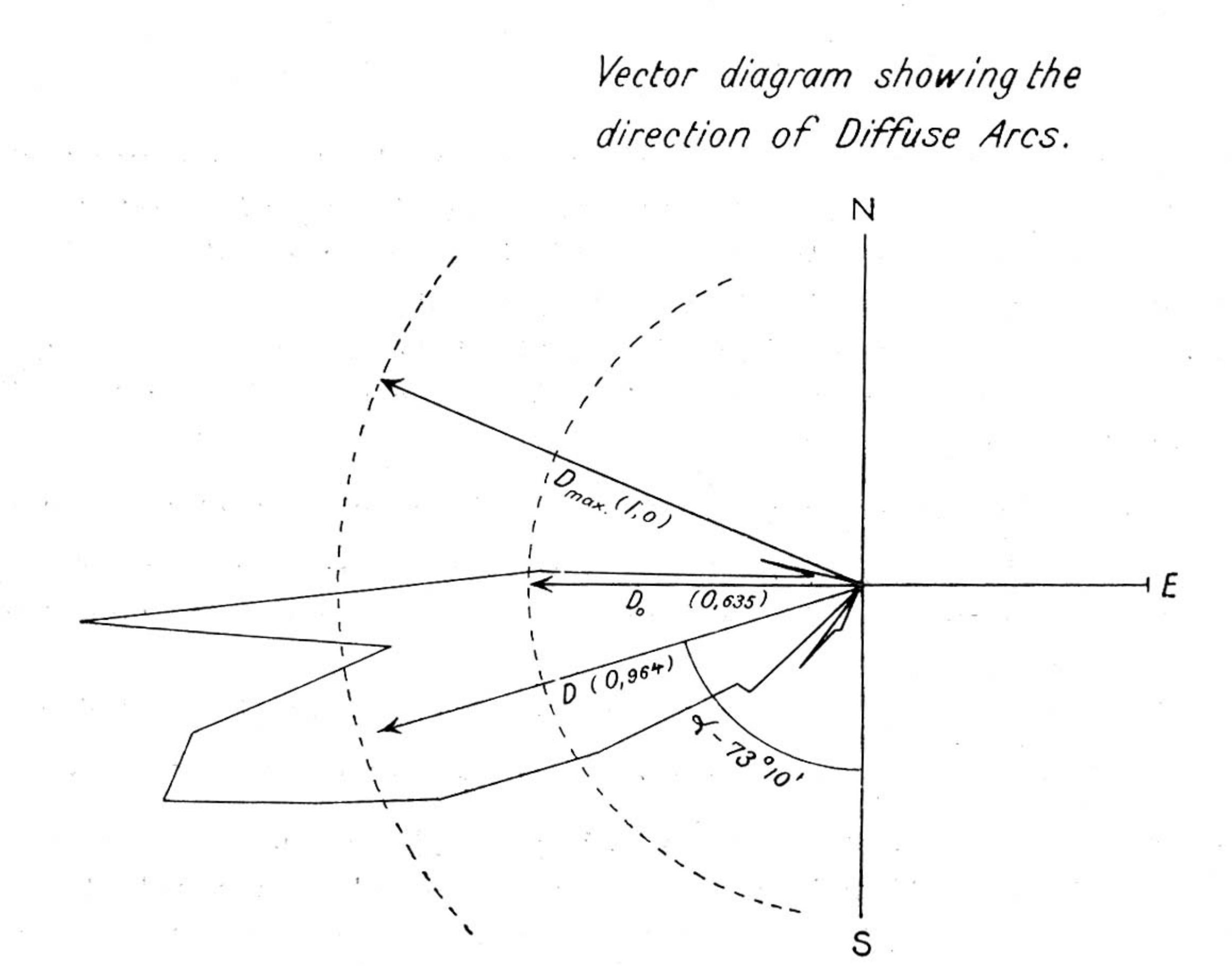


Fig. 23.

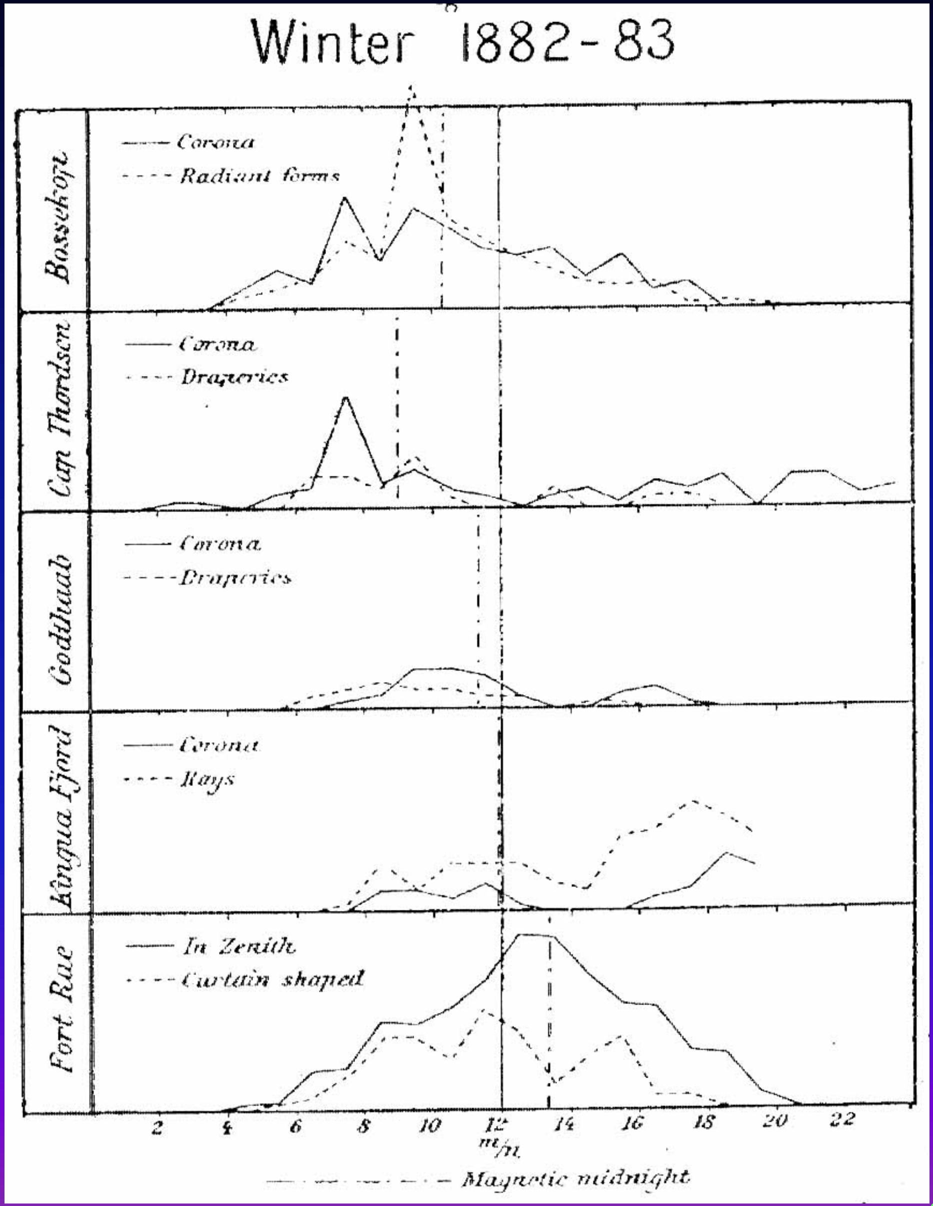
International Polar Year

- Because Bossekop was an IPY station, there was a data set that included measurments from all around the pole
- Bossekop was a candidate for Nordlysobservatoriet

Fig. 3. Das Wohnhaus. Die Thermometerhütte.

IPY Dirunal Occurrence Frequency

- Vegard gathered the data from around the pole and determined the average diurnal variation of the occurrence and arc alignment.
- It was not conclusively in support of the Birkeland – Størmer theory.



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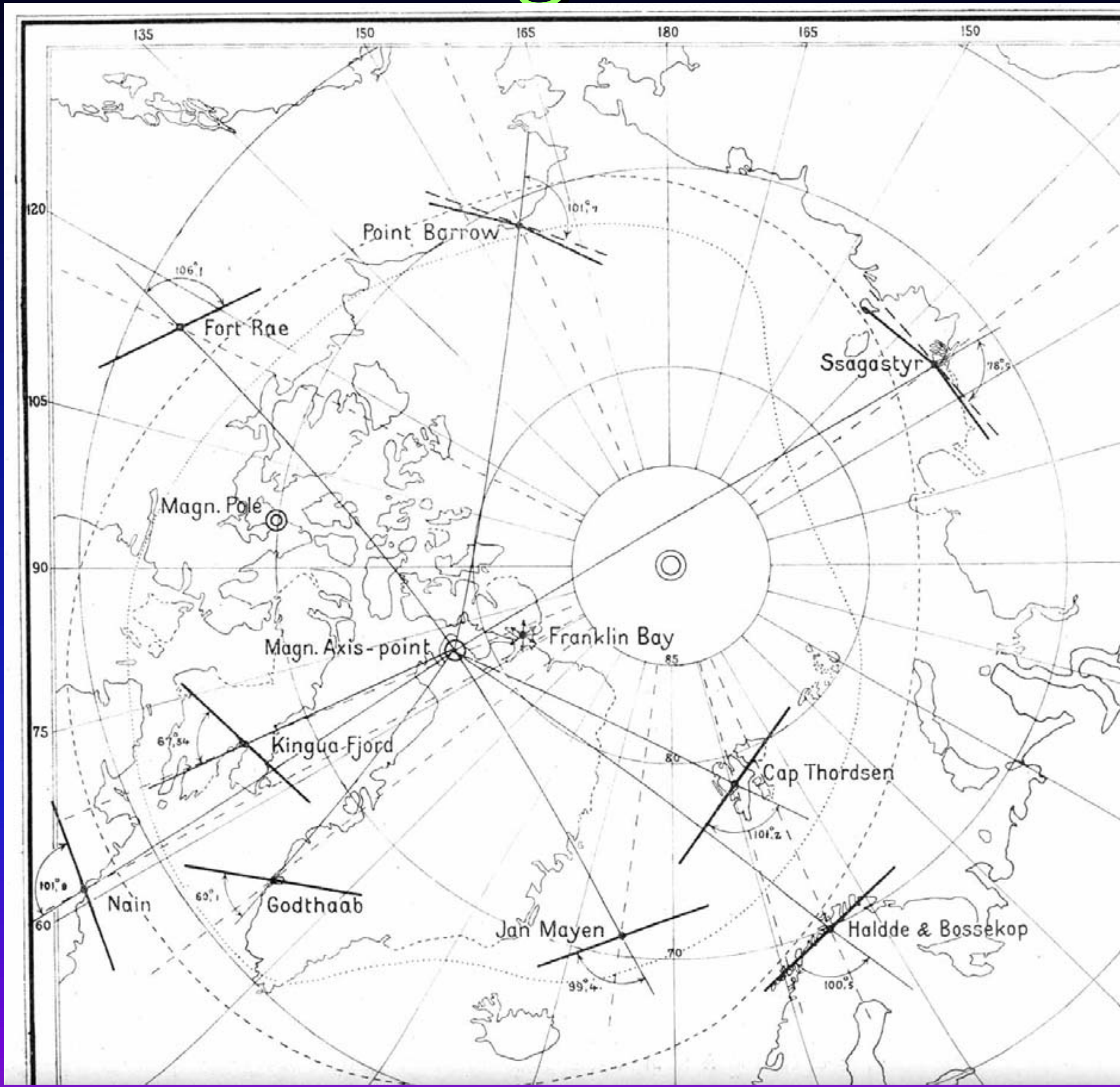


Bossekop, The Field Trip

THE POSITION IN SPACE OF THE AURORA POLARIS

FROM OBSERVATIONS MADE AT THE HALDDE-OBSERVATORY

1913–14

BY

L. VEGARD AND O. KROGNESS

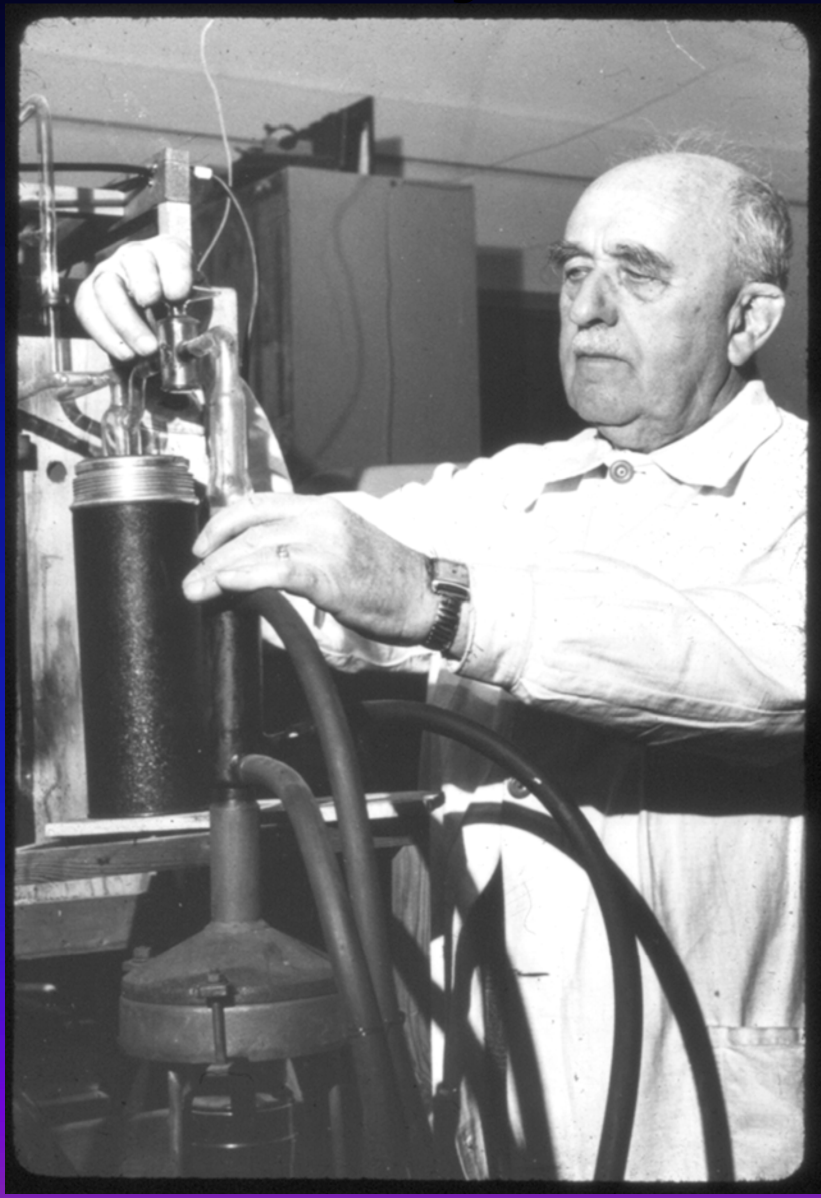
GEOFYSISKE PUBLICATIONER
VOL. I NO. 1

IN MEMORY OF OUR TEACHER

KR. BIRKELAND

Vegard in the Laboratory

- Vegard's laboratory work revolved around reproducing the auroral emission spectrum.



Vegard in the Laboratory

- His trips to various laboratories in Europe led him to use the most advanced techniques.

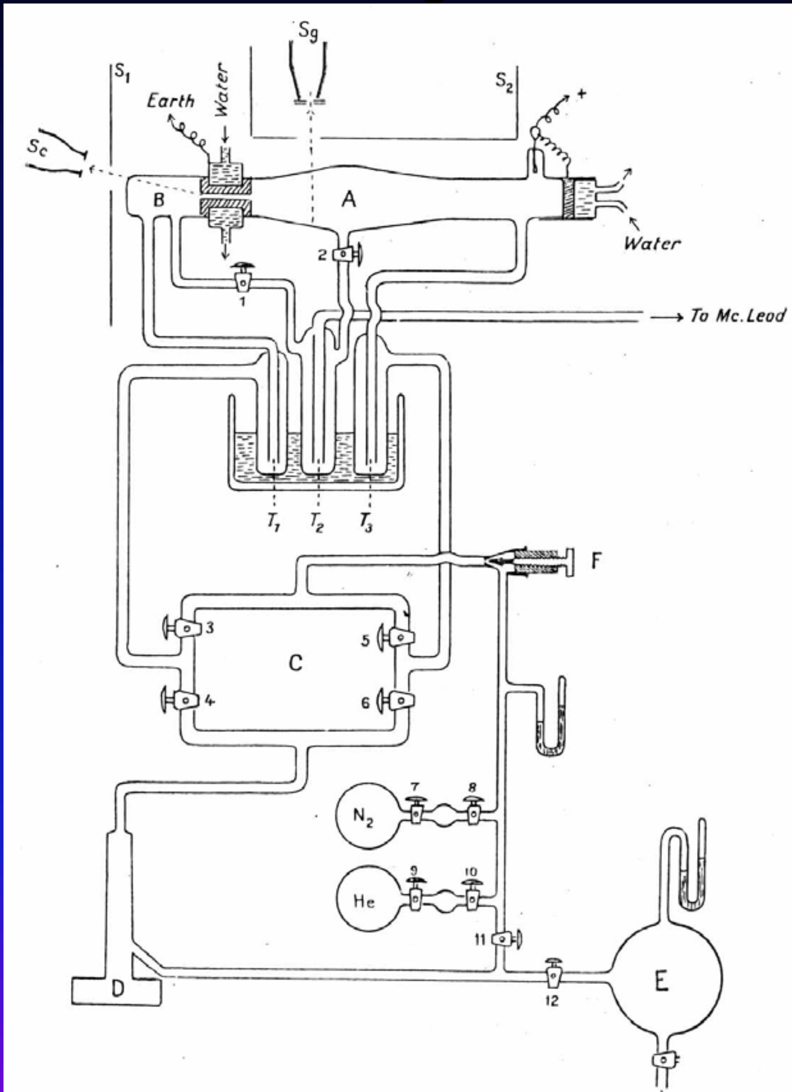
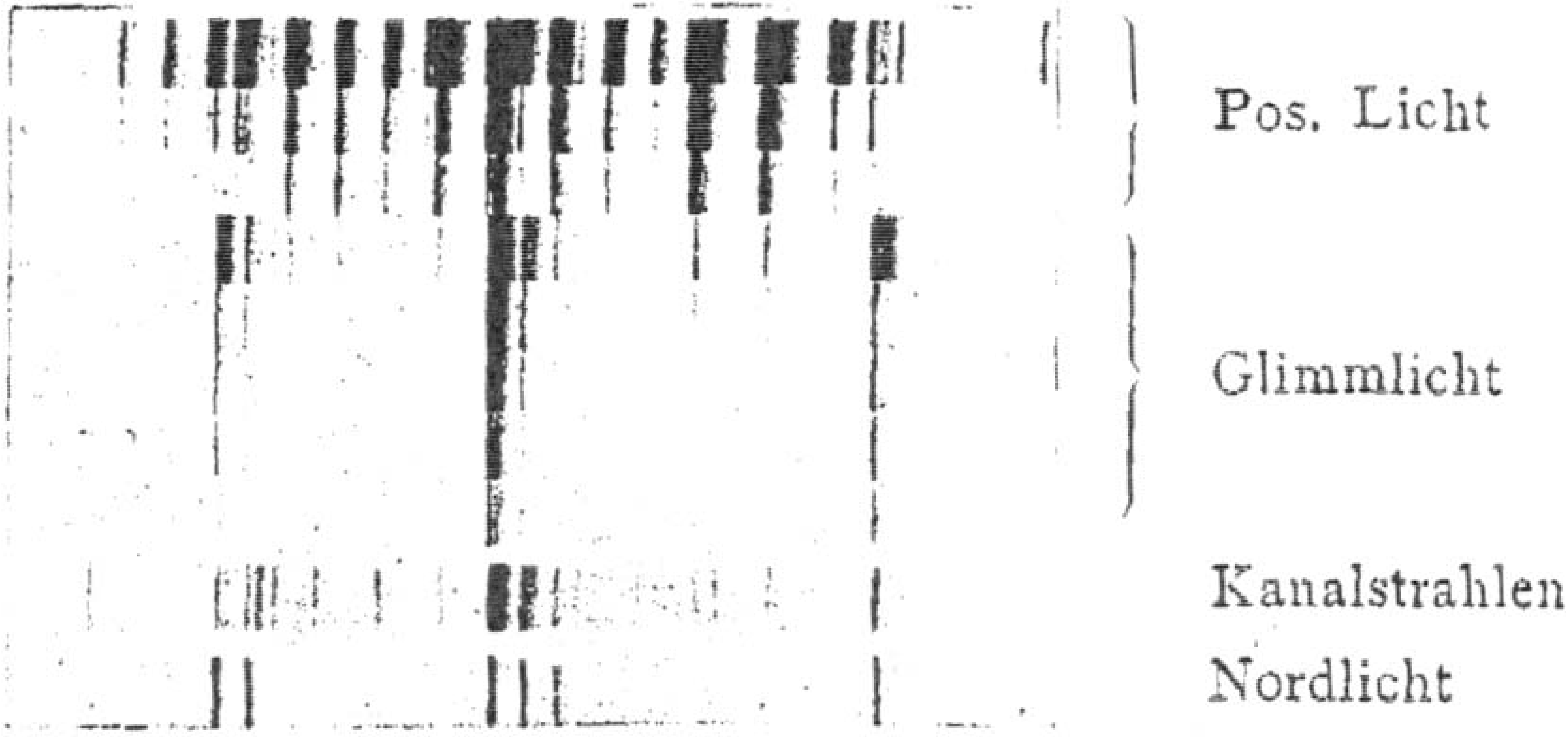


Fig 1.

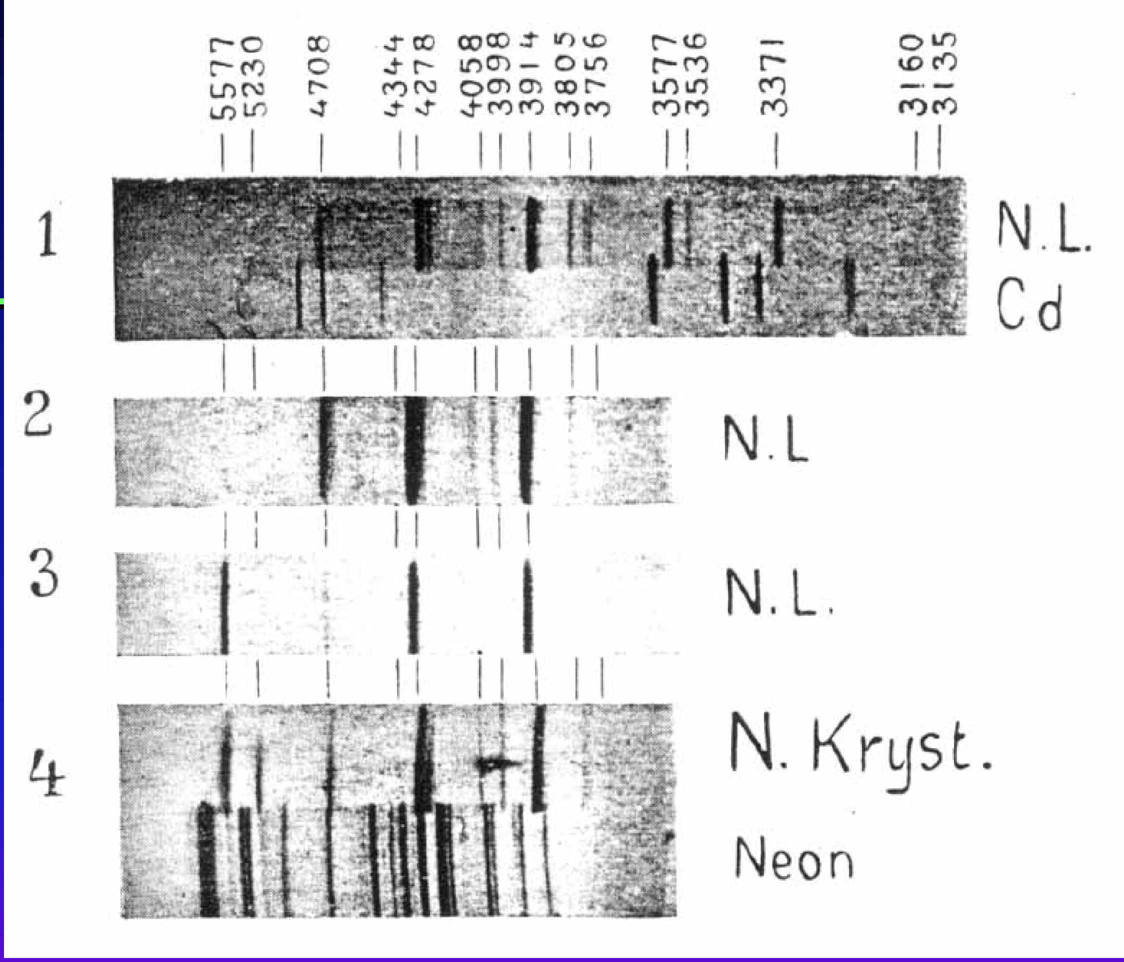
Vegard in the Laboratory



- He was able to reproduce many of the emissions he observed in the aurora.

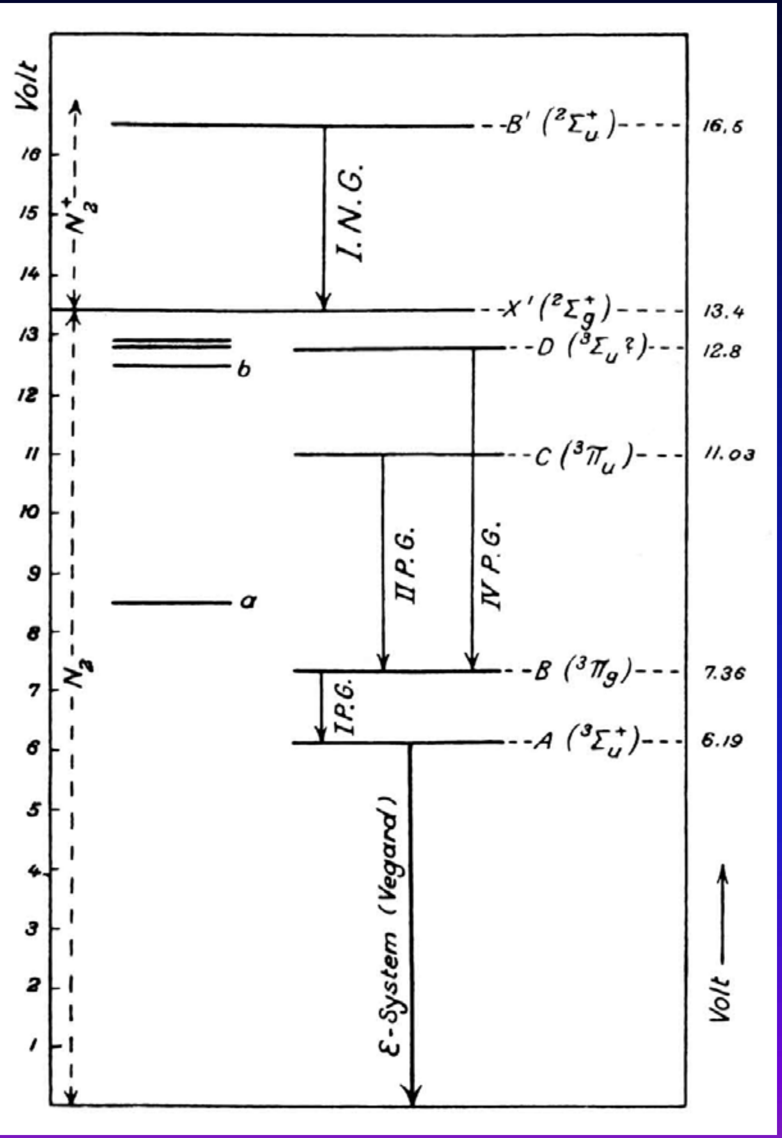
Vegard in the Laboratory

- His success in reproducing the auroral spectrum and in discovering the Vegard-Kaplan bands of N_2 by bombarding nitrogen crystals with electrons led him to believe that there was a layer of solid nitrogen particles in the atmosphere.



Vegard in the Laboratory

- Vegard discovered a forbidden band system of N_2.
- He called it the epsilon band (emission from the A state to the ground state X).



Vegard – Kaplan Bands

- Vegard observed the epsilon bands in the aurora.
- 2 years later, Joe Kaplan documented the exact level distribution in the laboratory.

Tromsø Geophysical Observatory

- Tromsø Meteorological Institute

Tromsø Meteorological Institute

- New spectrographs with larger dispersion and aperture were designed and constructed for the establishment of a spectrographic auroral observatory in Tromsø.

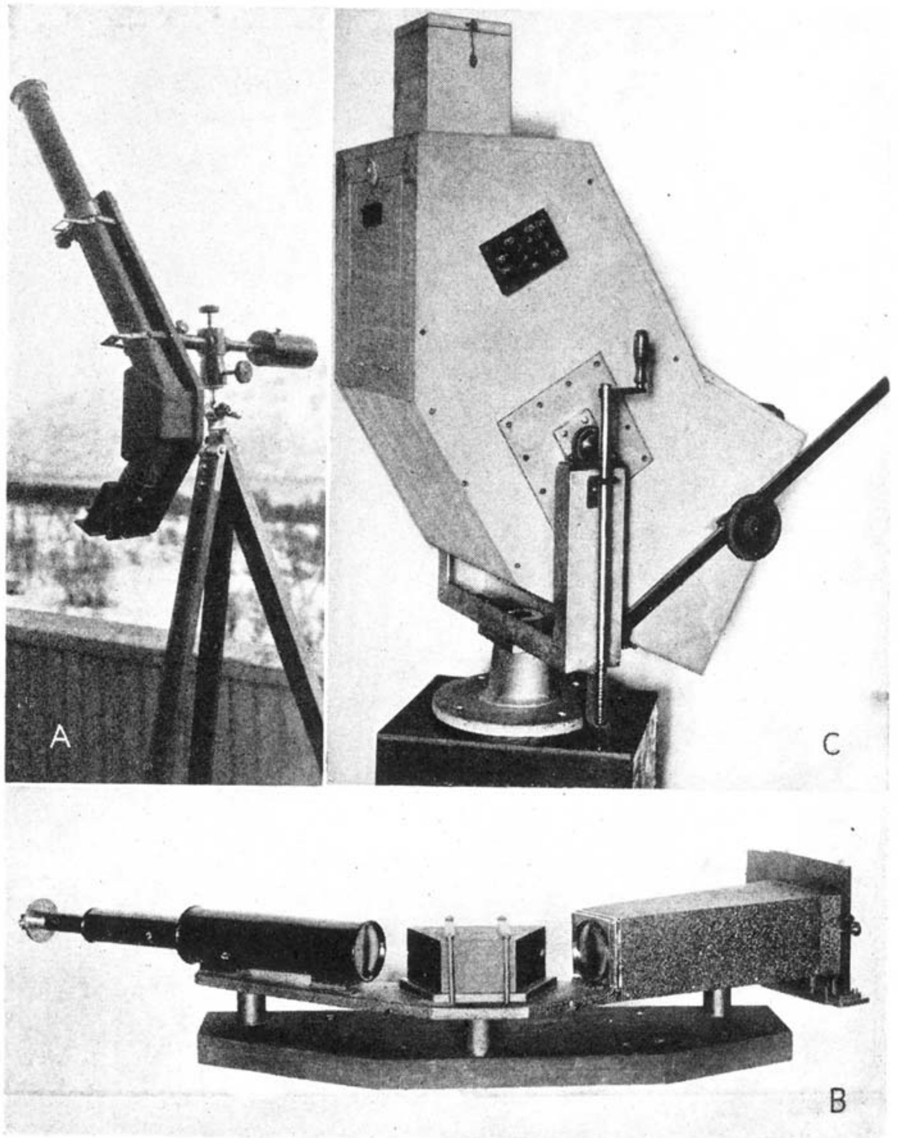
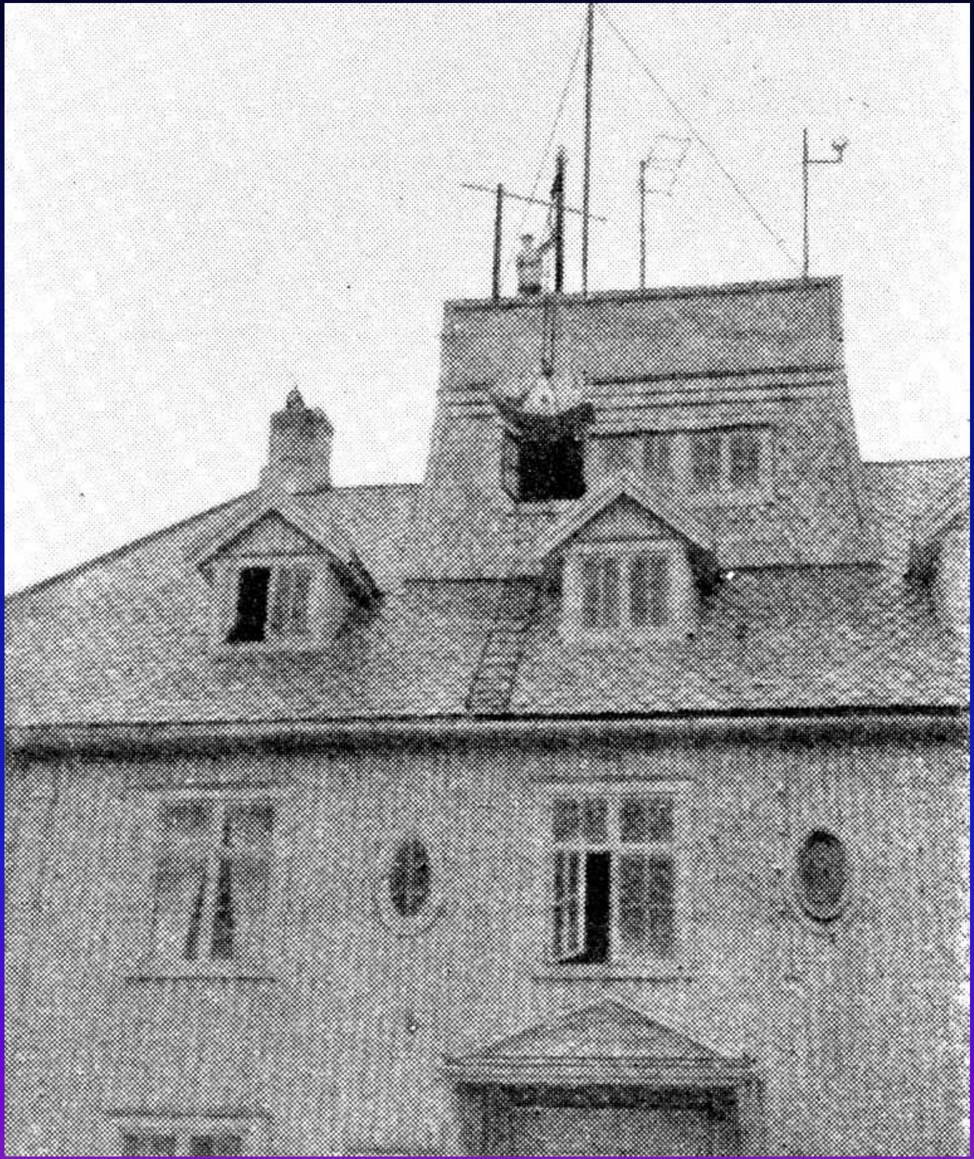


FIG. 13.—Various types of spectrographs.

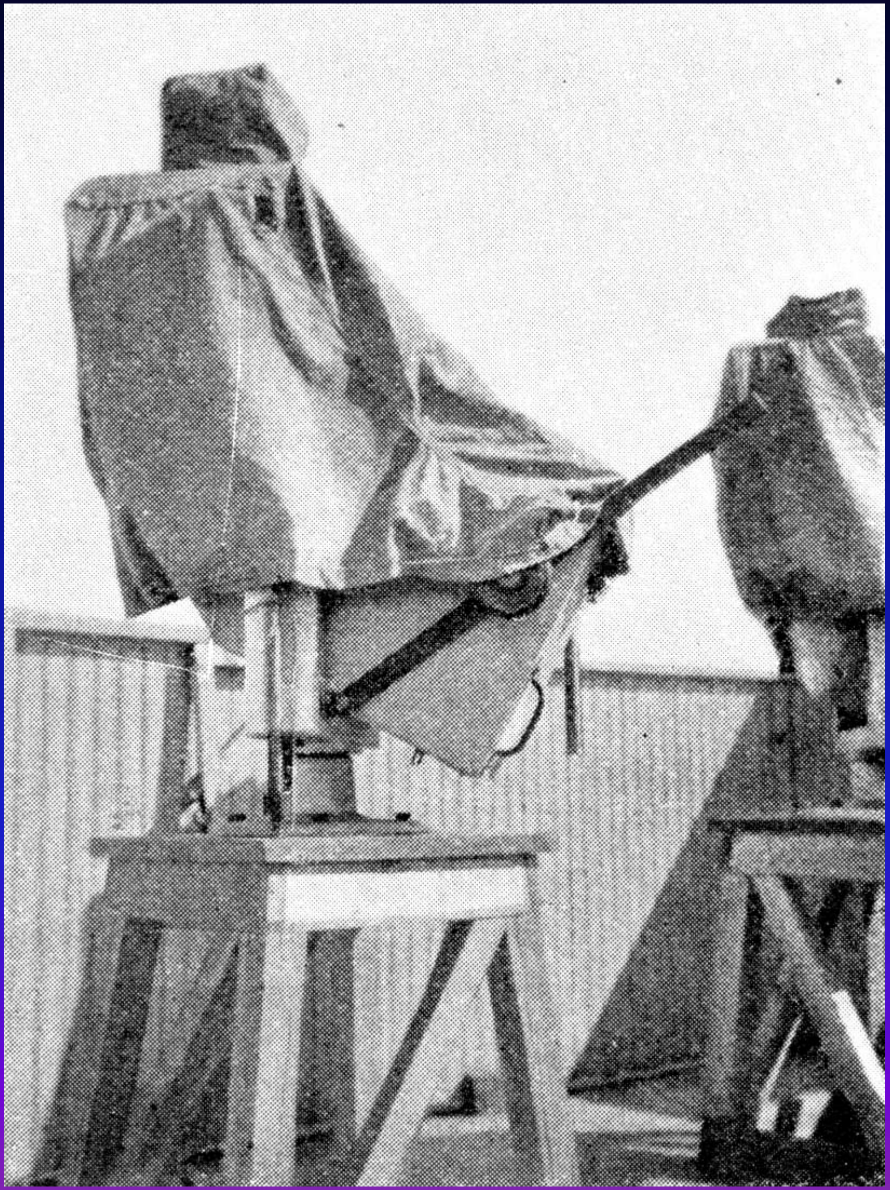
Tromsø Meteorological Institute

- Access to the observation platform on the roof of the geophysical observatory was too small for the large instruments.
- The large spectrographic equipment had to be lifted up to the platform from below.

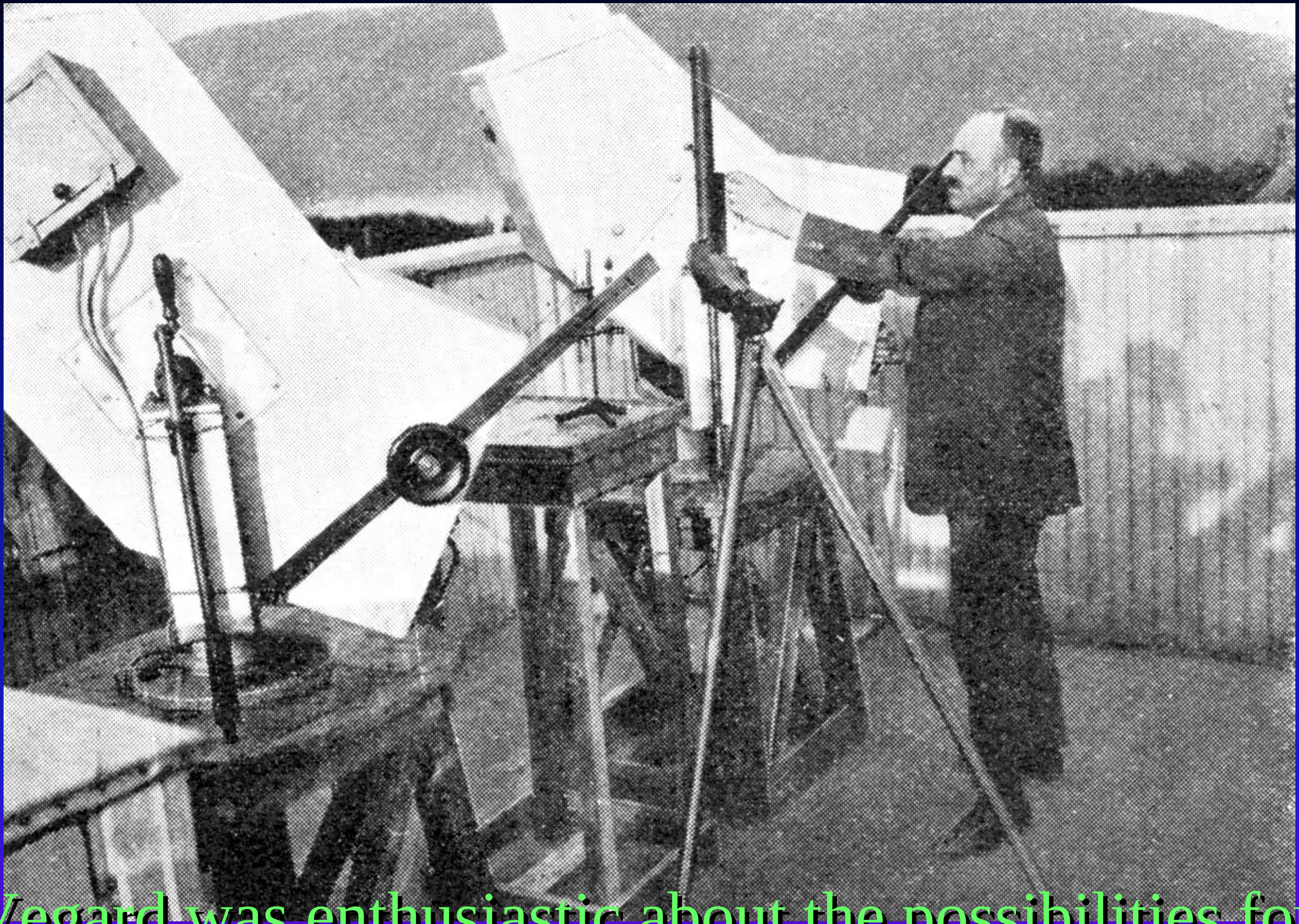


Tromsø Meteorological Institute

- The spectrographs could not be taken in out of the weather.
- Large canvas covers were fabricated to protect them.



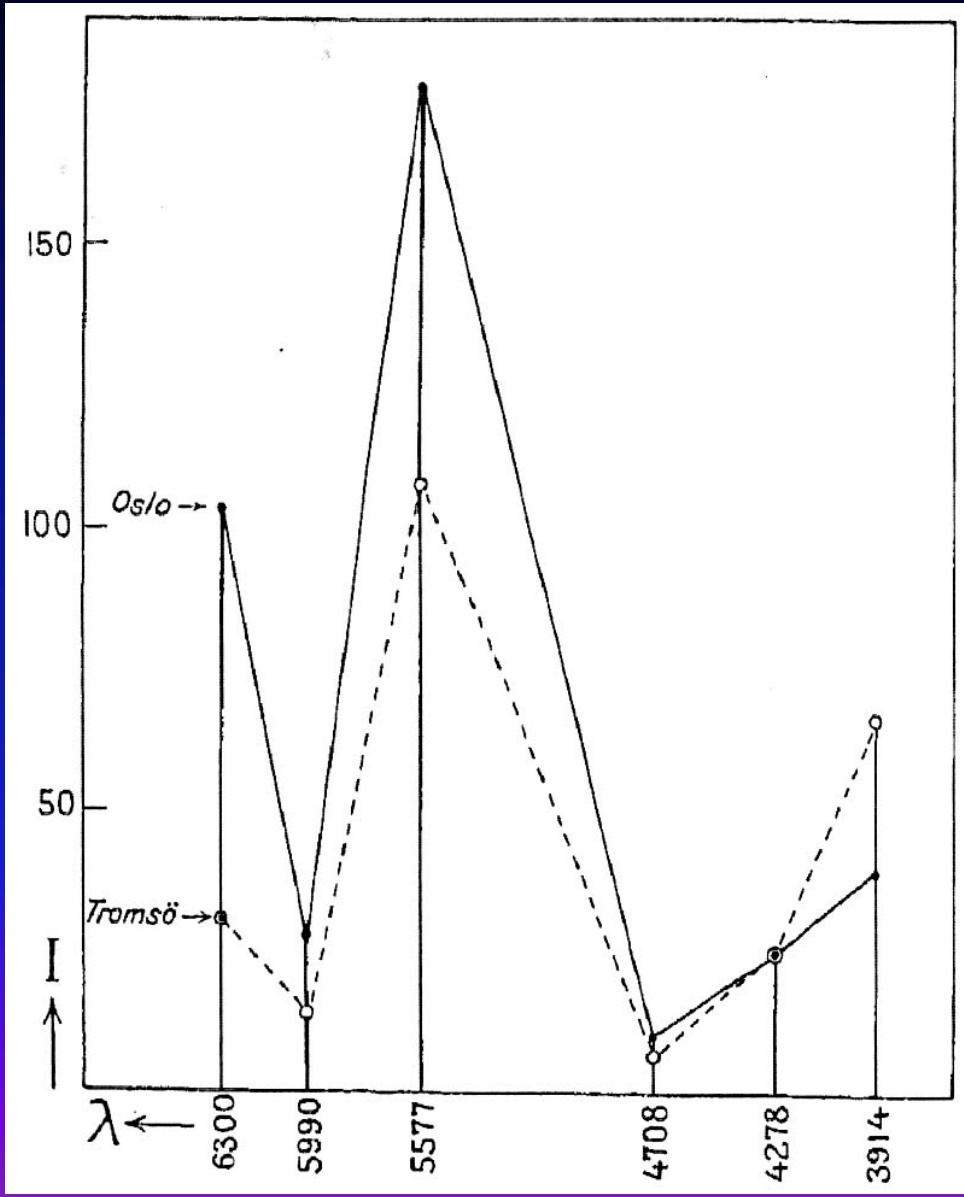
Tromsø Meteorological Institute



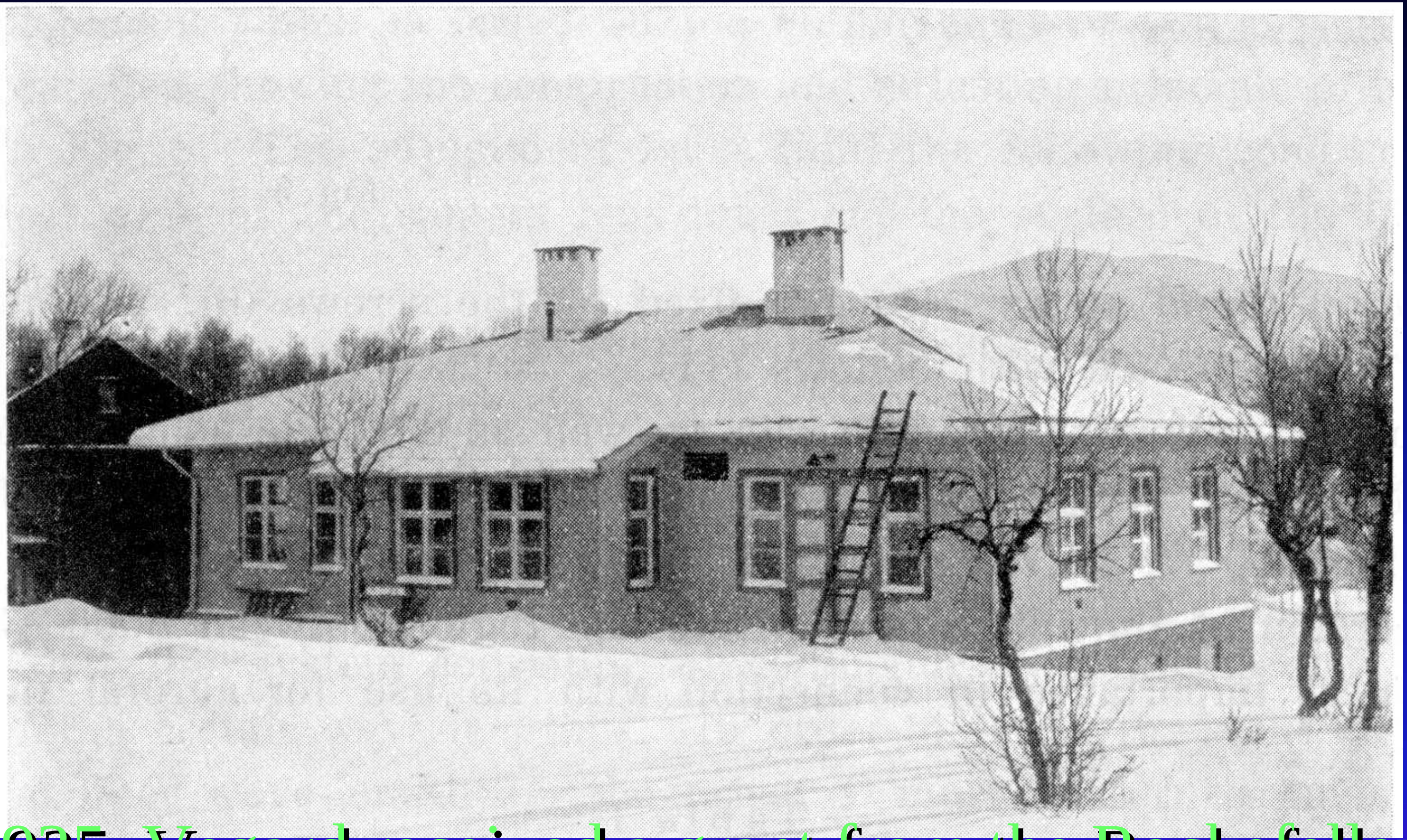
- Vegard was enthusiastic about the possibilities for observing from Tromsø.

Latitude Variations: Oslo-Tromso

- Vegard measured the difference in aurora between Oslo and Tromsø
- He found the red and green oxygen lines brighter in Oslo than farther north.

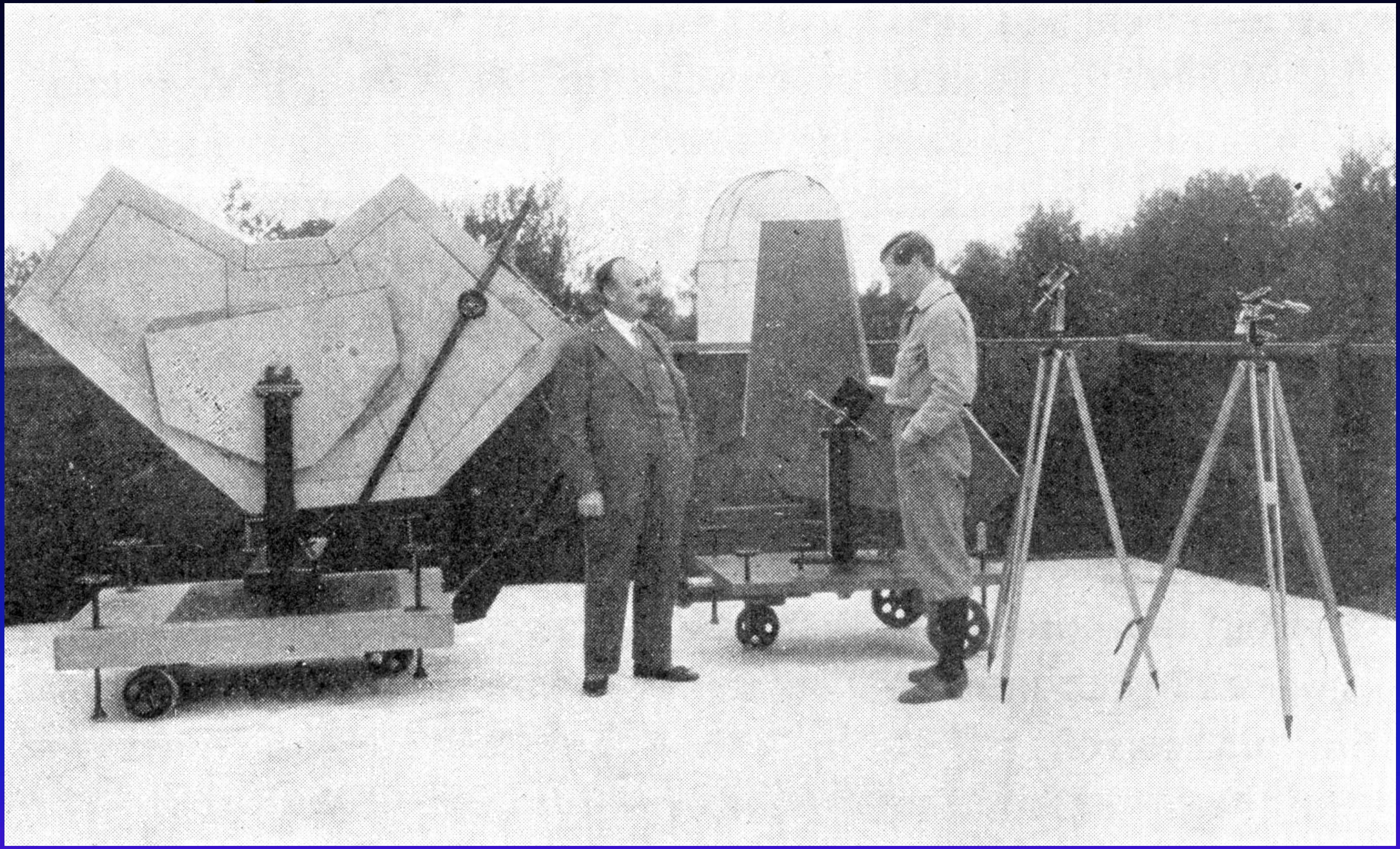


Nordlysobservatoriet I Tromsø



- In 1925, Vegard received a grant from the Rockefellers to set up Nordlysobservatoriet. It was established in 1930.
- Vegard headed the steering committee called Norsk Institute for Kosmisk Fysikk.

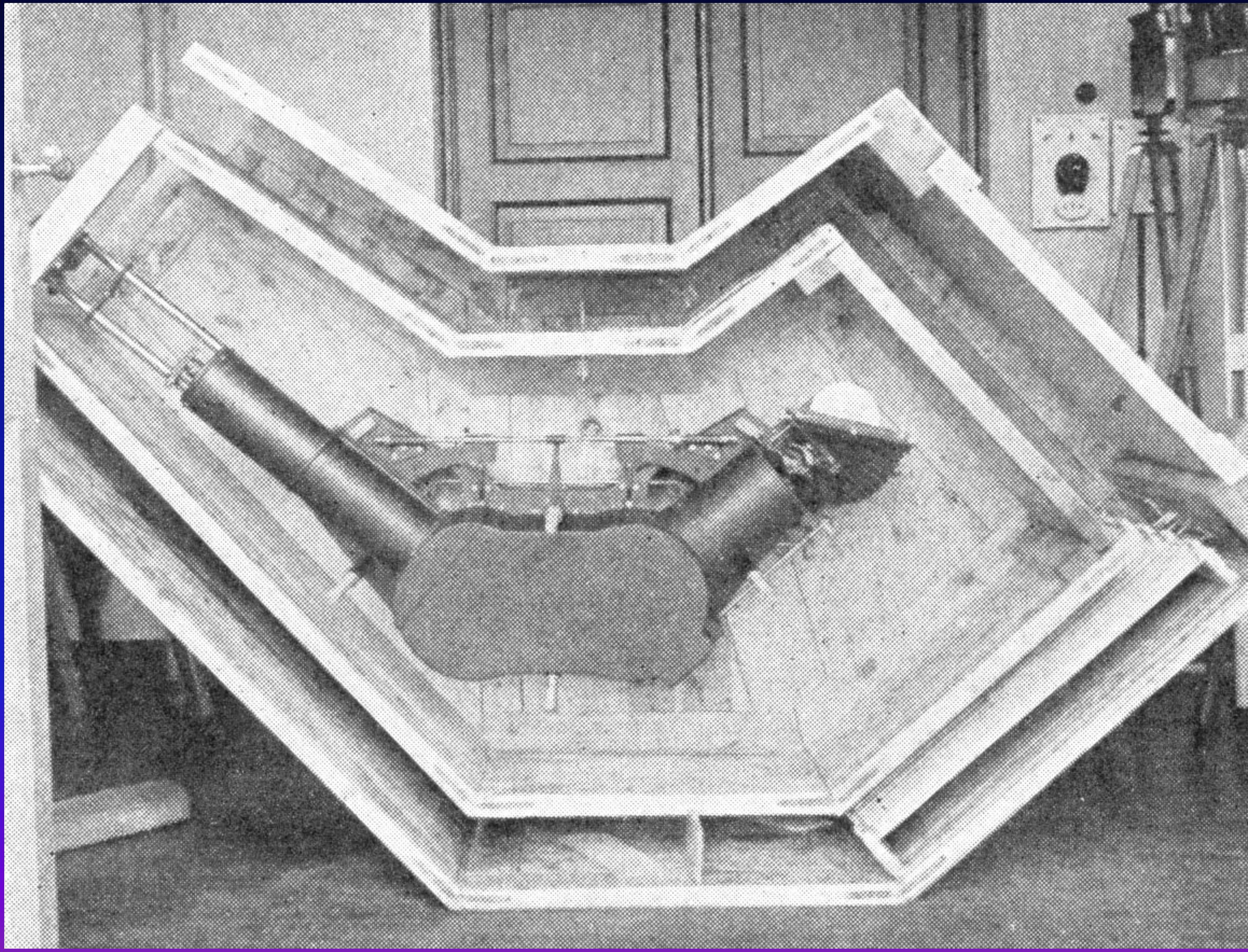
Nordlysobservatoriet I Tromsø



- Vegard and Einar Tønsberg pose with the new observing instruments on the platform at Nordlysobservatoriet

Nordlysobservatoriet I Tromsø

- A double wall was built to keep the large spectro-graph warm



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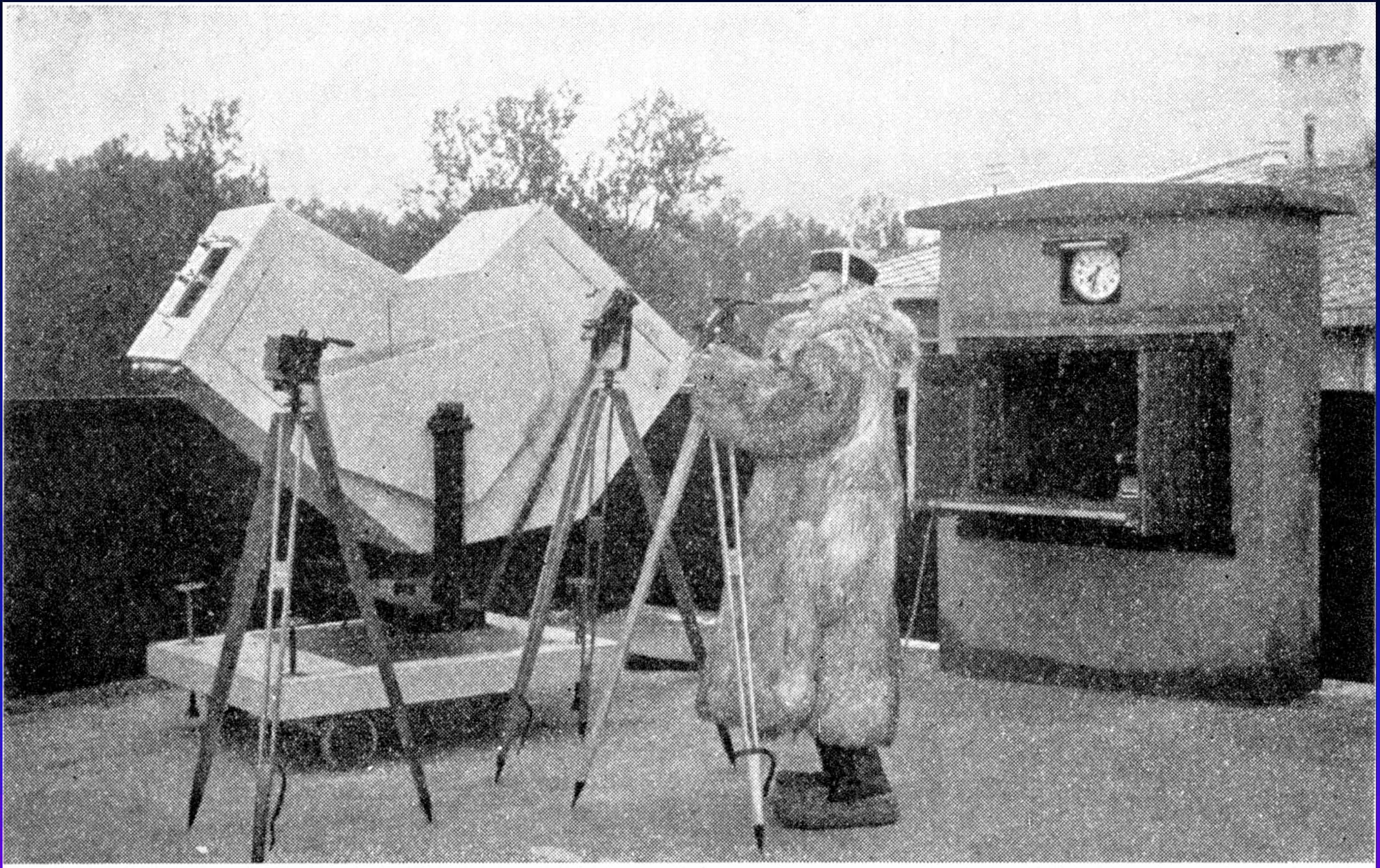
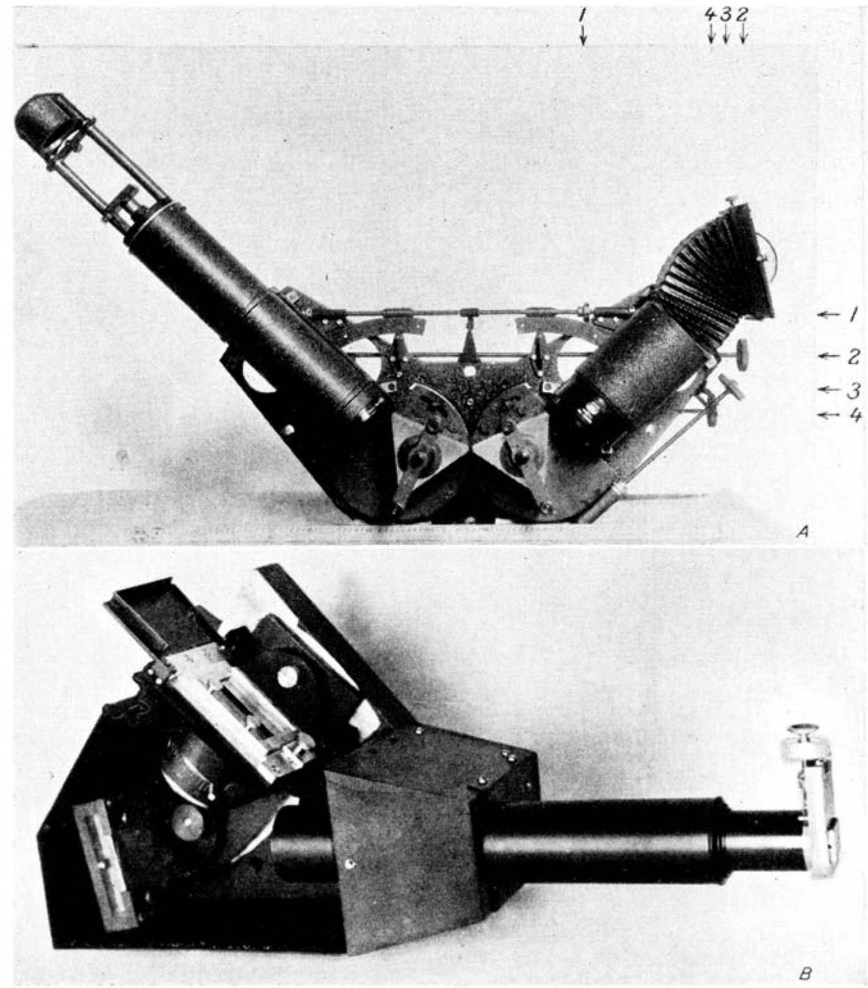


Fig. 1 c. Observation Platform with “stand” and instruments.

Auroral Spectrographs

- Vegard used various spectrographs throughout his career.
- He designed many new and faster instruments, but basically the only new technology he had at hand was the use of a new film for long astronomy exposures in the 1930s.



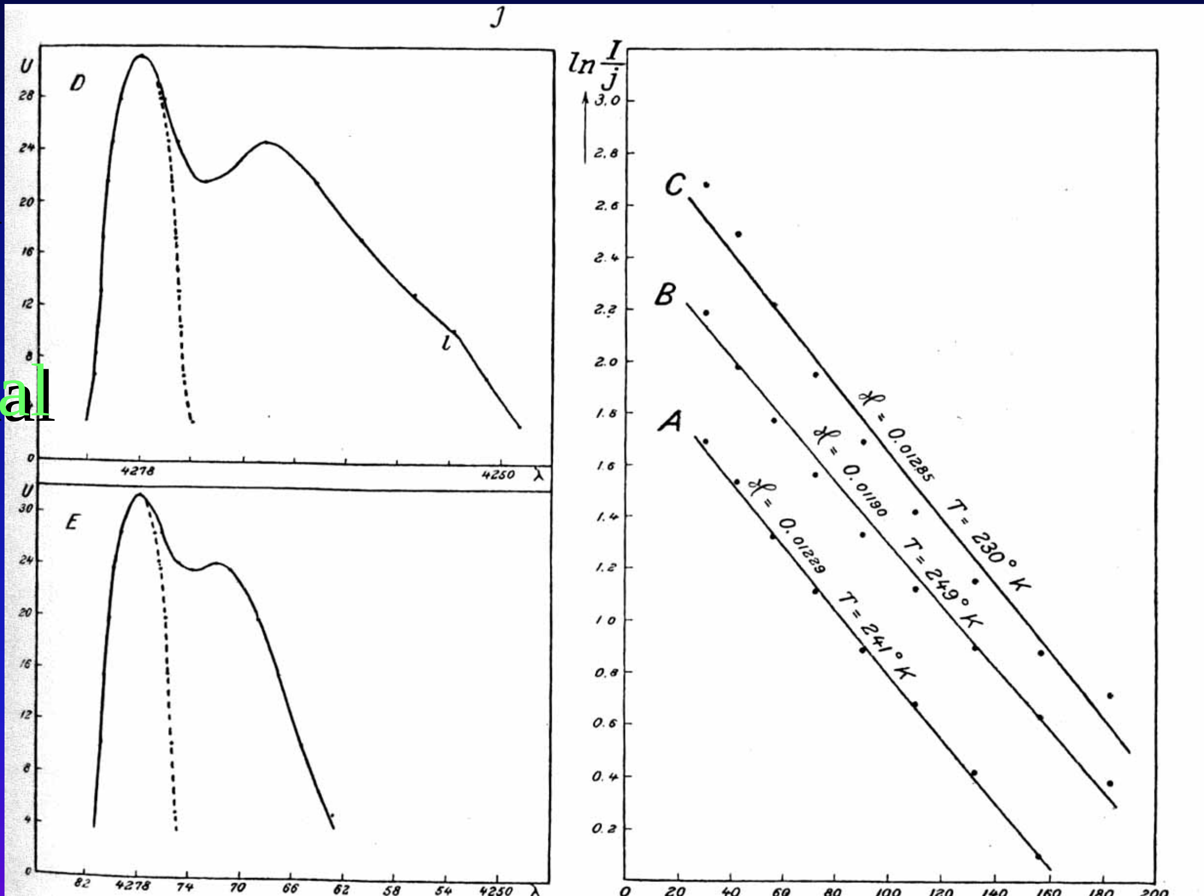
—Spectrographs; (A) with adjustable glass optical system and (B) with grating of high light-power for use in infrared region.

Norwegian Cosmic Physics

Changes in scientific instrumentation in the second half of the 20th century were not imaginable in Vegard's time.

Temperature of the Aurora from N_2^+

- Vegard was the first to measure the temperature of the atmosphere in which the aurora occurs.
- He used the rotational structure of nitrogen bands.
- His long exposures prevented him from finding the variation with height.



FIGS. 3 AND 4

Auroral Hydrogen Emission

- The detection of the hydrogen emission at 4861 A was the first confirmation of the theory that the aurora was caused by energetic particles in electrically neutral rays.

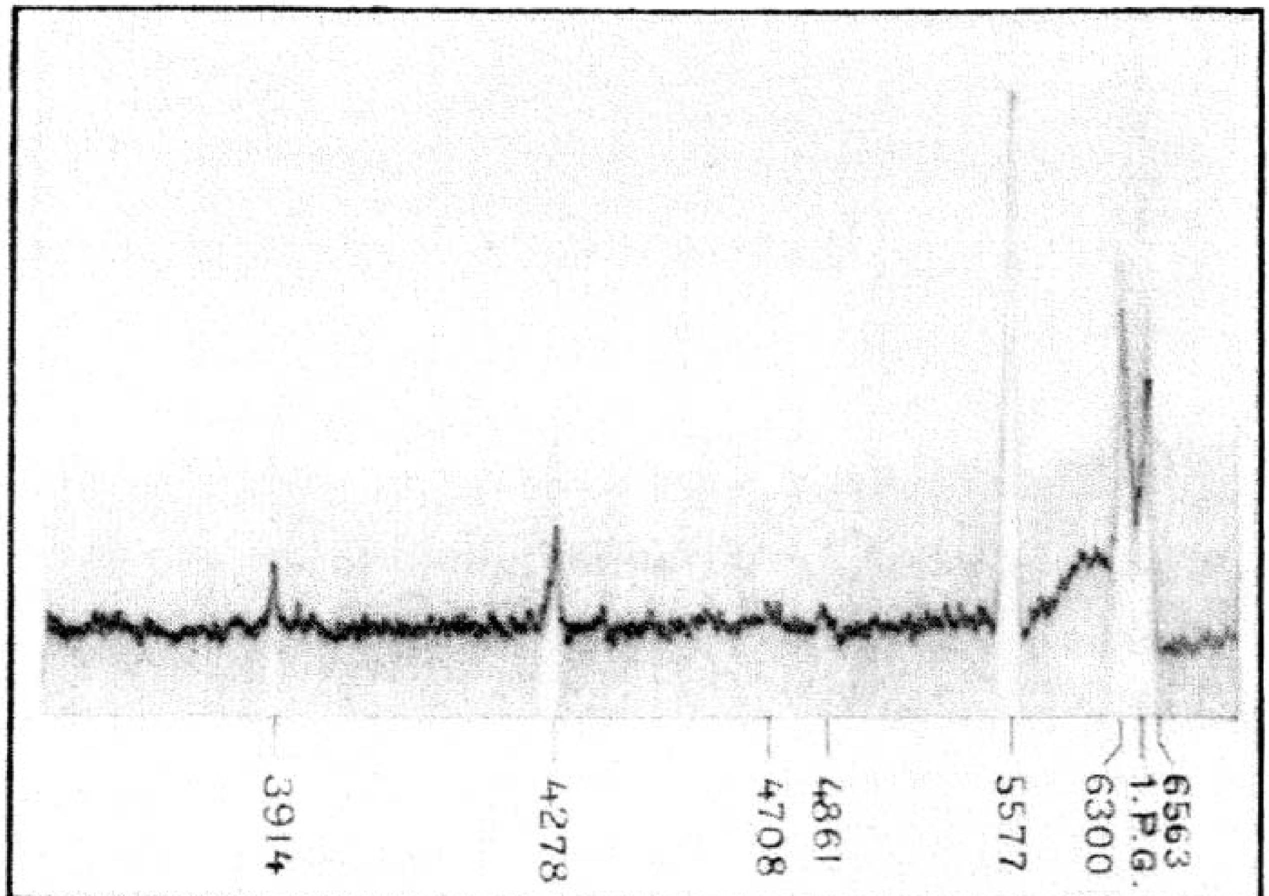
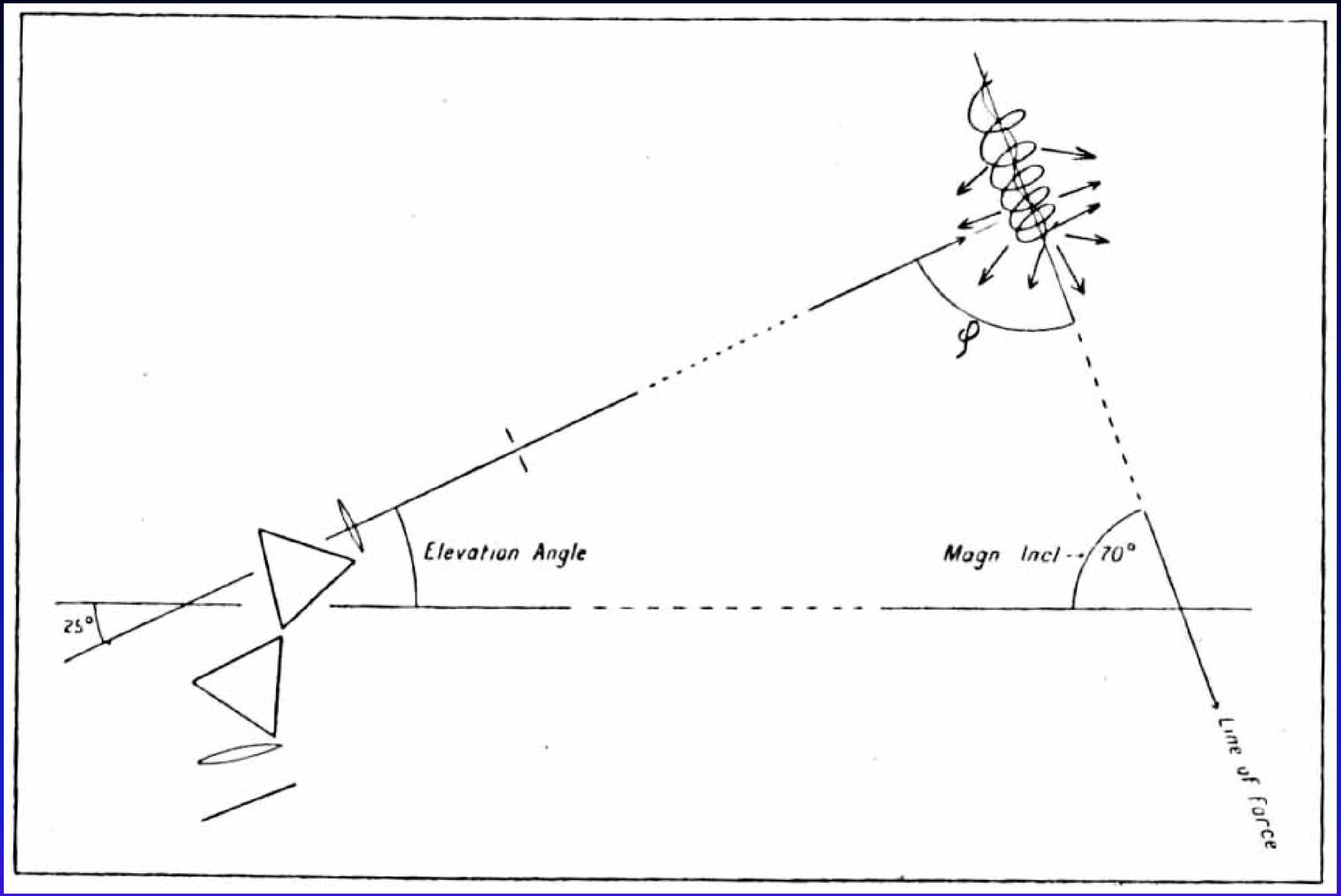


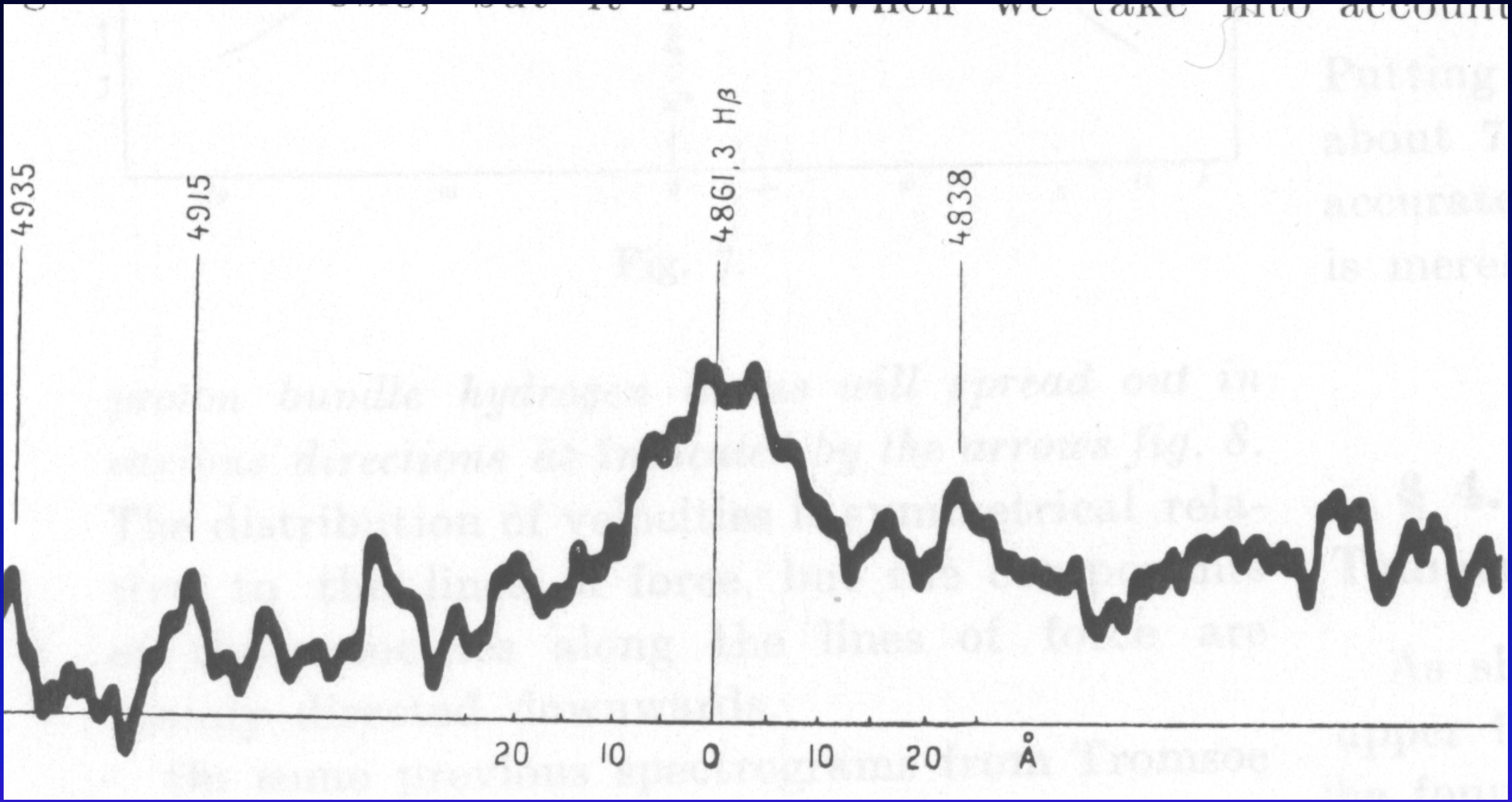
FIG. 1—MICROPHOTOMETRIC CURVE OF AURORAL SPECTRUM AT OSLO, OCTOBER 18, 1939

Auroral Hydrogen Emission



- Horizon observations broaden but do not shift.
- Zenith measurements broaden and shift.

Auroral Hydrogen Emission



- Vegard had seen the Doppler effect since 1939, but did not have the sensitivity and resolution to see the Doppler shift.

Auroral Hydrogen Emission

- Carl Gartlein (shown with his assistant, Mrs. Gartlein) observed H emission in the September 1950 aurorae.

Auroral Hydrogen Emission

- Gartlein had the same problem as Vegard. His spectrographs were looking at the horizon so he measured Doppler broadening, but not Doppler shift.

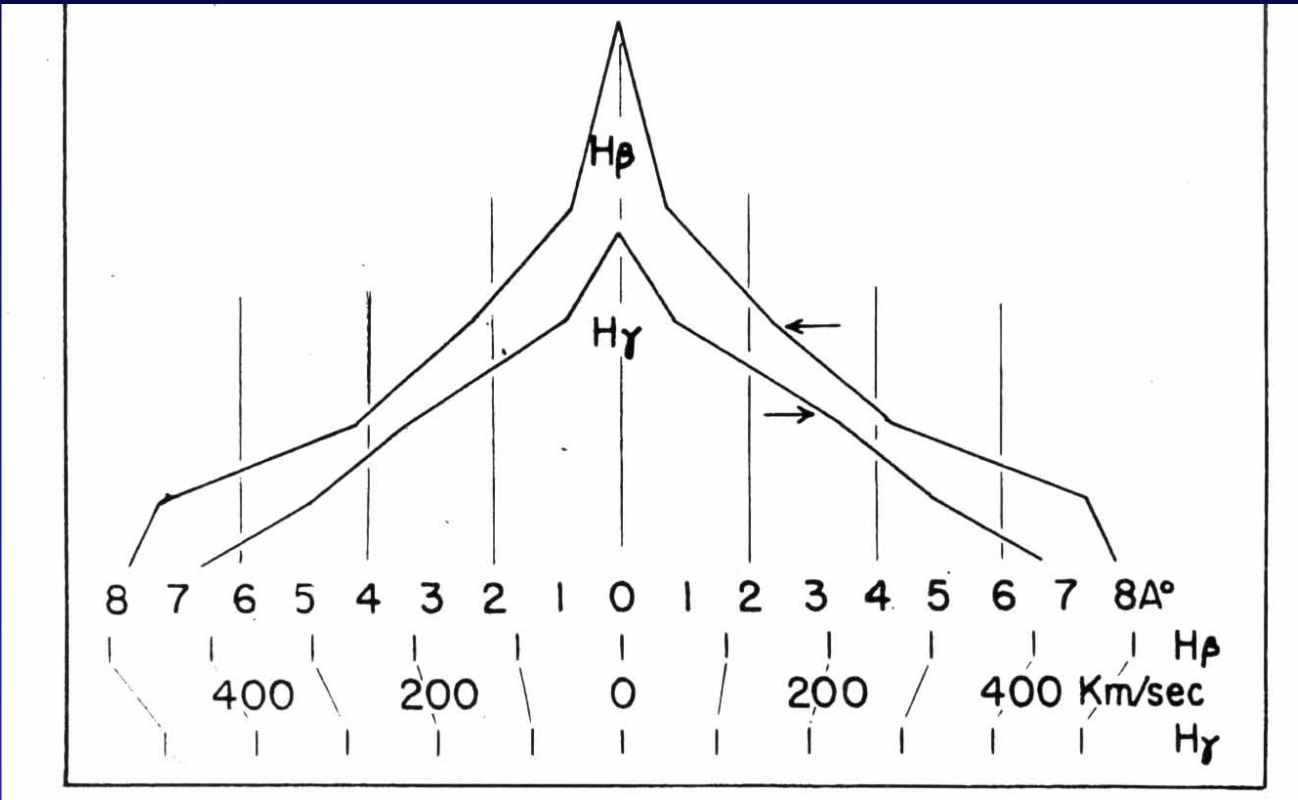
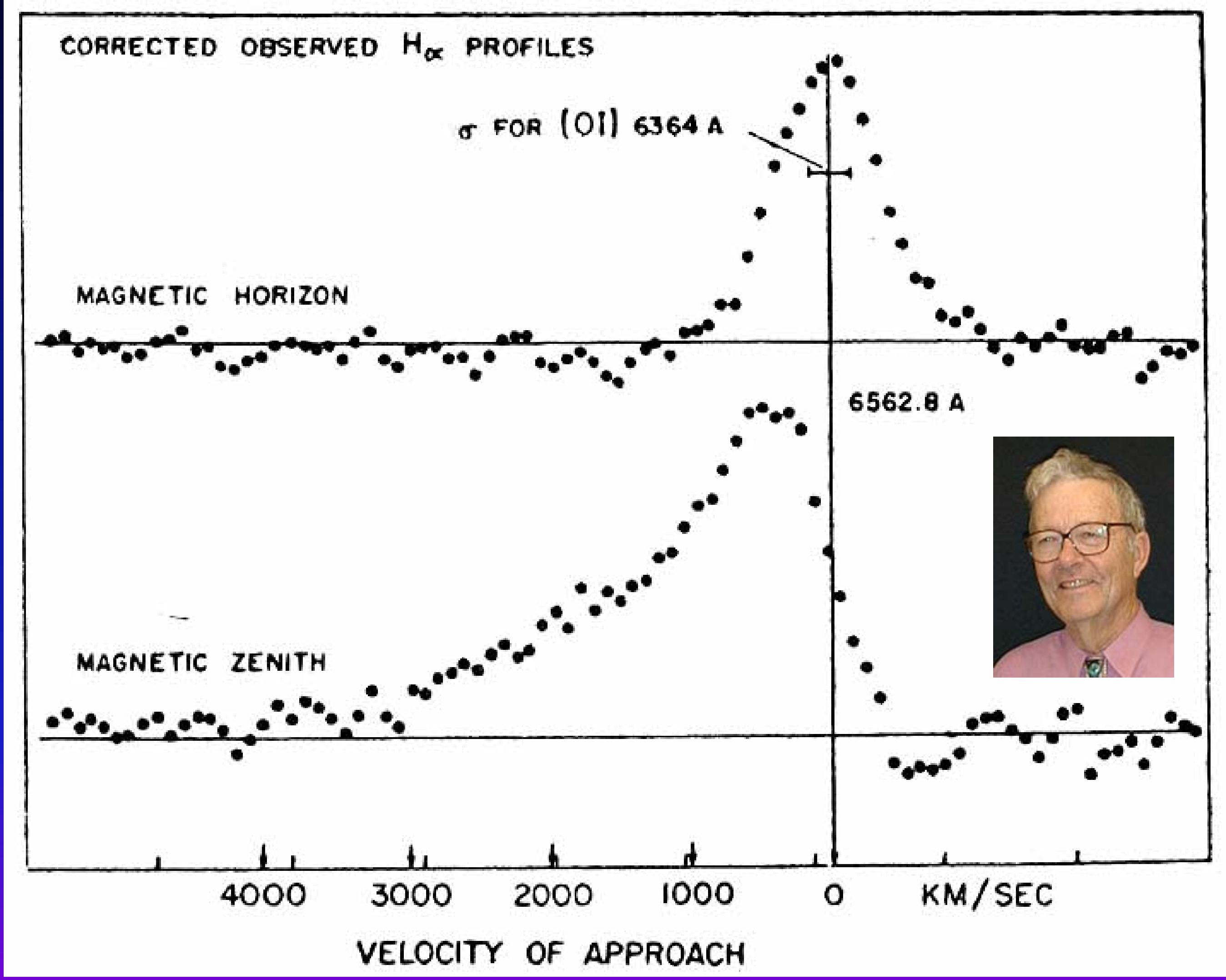


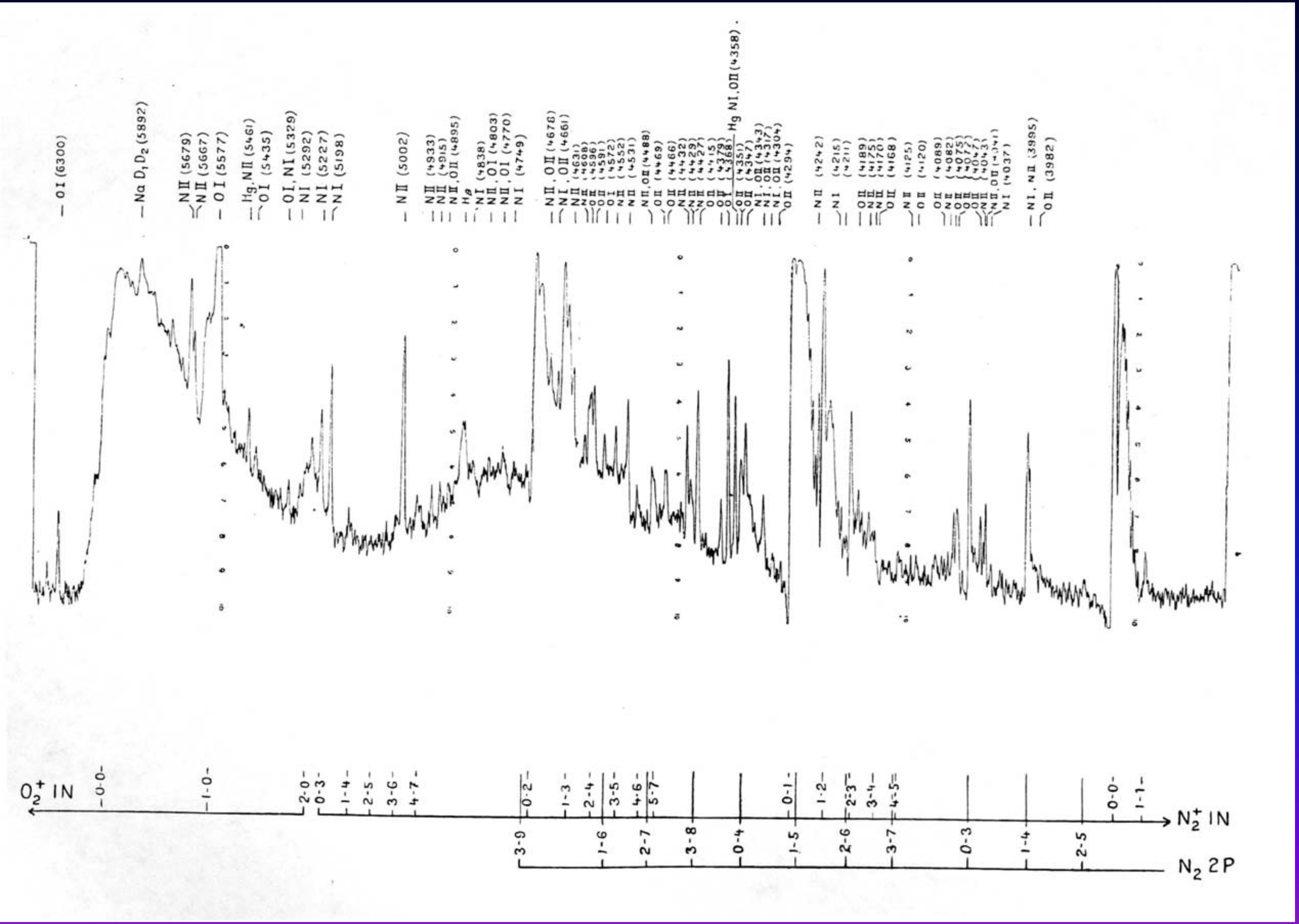
Fig. 2--Plot of the intensity of two hydrogen lines versus angstrom width and line of sight velocity

Auroral Hydrogen Emission

- Aden Meinel used the new gratings blazed to reflect more light into a single order.
- He was able to record H emission in the zenith from Wisconsin in August, 1950.



“>500 Auroral Emissions”



Professor Lars Vegard’s Contribution to Auroral Research

Norway at the Turn of the Century

- Lars Vegard was a world-class scientist.
- He was at the same time *helnorsk.*